

**Cognition and Personality in Older Age:
From Long-Term Development to Short-Term Dynamic Processes in
Daily Life**

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Abstract

Aging is a multidimensional process including physical, psychological and social changes. Furthermore, several cognitive abilities tend to decline with increasing age. However, older adults differ in the change and decline of different cognitive abilities. It is consequently of interest why some individuals maintain or even improve their cognitive abilities, whereas others show cognitive decline as they age. Amongst other factors, education and personality can explain at least some of the variability in cognitive aging. Therefore, the main goal of the present thesis was to gain a more elaborated picture about the role of education and personality in cognitive aging, whereas the emphasis was on the latter. Specifically, it was of interest to examine the longitudinal associations between cognition and personality that contribute to healthy aging over years as well as over days. As such, there was a shift from long-term longitudinal development (Studies 1-3) to short-term dynamic processes (Studies 4-5).

Study 1 investigated possible differences in cognitive aging due to education. Study 1 was based on longitudinal data of two groups (236 averagely and 39 highly educated older adults) across five years. The main results suggest that indeed highly educated individuals (i.e., retired professors) outperformed averagely educated individuals in perceptual speed and working memory tasks, it cannot be shown that education has a beneficial effect on cognitive development over five years. Furthermore, cognitive engagement may be a supportive factor of cognitive performance: Averagely educated adults who reported high levels of cognitive engagement kept up with the professors' performance in a perceptual speed task.

Study 2 examined whether levels of six different cognitive abilities were related to levels of three different personality traits across four years. Study 2 was based on longitudinal data of 236 older adults. In general, few and weak relations between the two domains were found. Only reasoning was related to openness and conscientiousness was related to verbal knowledge four years later. Consequently, it seems reasonable to scrutinize whether or under

which circumstances cognitive abilities (maximal performance) are linked to personality traits (typical behaviors).

Study 3 tested whether cognitive complaints mediated the effect of cognition on emotional stability and vice versa across 12 years. Study 3 was based on longitudinal data of 500 older adults. The results showed that cognitive complaints mediated the effect of cognition on emotional stability across 12 years, but not the effect of emotional stability on cognition. It is thus indicated that cognitive resources serve as a protective factor for emotional stability in older age.

Study 4 investigated the daily associations between (a) open behaviors and cognitive engagement as well as (b) neurotic behaviors and cognitive complaints at the between-person and within-person level of analysis. Study 4 was based on ambulatory assessment data of 136 older participants. Multilevel analyses confirmed the hypothesized positive association between daily open behaviors and daily cognitive engagement at both levels of analysis. For daily neurotic behaviors and daily cognitive complaints, no relationship was found neither at the between-person level nor at the within-person level. Based on the findings for open behaviors and cognitive engagement, future intervention studies should test whether a simple intervention with the goal to encourage individuals to act more openly may be successful to increase cognitive engagement.

The aim of Study 5 (feasibility study) was to innovatively assess eye movements within the scope of a real-life assessment paradigm. Furthermore, it was of interest to explore possible associations between personality traits and these eye movements. Study 5 was based on eye tracking data of 38 individuals who did their grocery shopping while wearing an eye tracker (real-life assessment paradigm). Study 5 demonstrated the feasibility of grocery shopping as a real-life assessment paradigm with older adults and provides insights into the eye tracker data collection in real life as well as some specific practical recommendation for future studies.

Based on the findings of the current thesis, three main implications for future research arise. First, the investigation of long-term development and short-term dynamic processes should be merged. Second, elements from both cognitive and personality psychology should be combined to design individualized interventions. Third, the examination of cognition-personality investigations should be amplified to satisfy the perspective of healthy aging in a more holistic sense that is based on the lifespan.

Zusammenfassung

Altern ist ein multidimensionaler Prozess, der unter anderem von physischen, psychischen und sozialen Veränderungen geprägt ist. Ebenso tendieren diverse kognitive Fähigkeiten dazu, mit zunehmendem Alter nachzulassen. Ältere Menschen unterscheiden sich jedoch in der Veränderung und Abnahme von verschiedenen kognitiven Fähigkeiten. Das heisst, dieser kognitive Abbauprozess verläuft nicht für alle Individuen gleich. Folglich ist es von Interesse, warum die einen älteren Menschen ihre kognitiven Fähigkeiten aufrechterhalten oder sogar verbessern können, während andere ein kognitiver Abbau zeigen. Bildung und Persönlichkeit sind unter anderem zwei Faktoren, die zumindest ein Teil der Variabilität des kognitiven Alterns erklären können. Darum war das Hauptziel der vorliegenden Dissertation, die Rolle von Bildung und Persönlichkeit beim kognitiven Altern zu untersuchen, wobei der Fokus auf letzterem lag. Es war also insbesondere von Interesse, die längsschnittlichen Assoziationen zwischen Kognition und Persönlichkeit, welche über Jahre und Tage zum gesunden Altern beitragen, zu untersuchen. Die vorliegende Dissertation fokussierte also auf zwei zeitliche Perspektiven, nämlich auf die längerfristige Entwicklung (Studien 1-3) sowie auf die kurzzeitigen dynamischen Prozesse im Alltag (Studien 4-5).

Studie 1 untersuchte, ob sich Unterschiede im kognitiven Altern durch Bildung erklären lassen. Diese Studie basierte auf Längsschnittdaten über fünf Jahre von zwei Gruppen, die sich in Bezug auf ihre Bildung unterschieden haben (236 durchschnittlich gebildete und 39 hochgebildete ältere Erwachsene). Die Resultate von Studie 1 zeigen, dass zwar hochgebildete Personen (Professoren im Ruhestand) in kognitiven Aufgaben zur Wahrnehmungsgeschwindigkeit und zum Arbeitsgedächtnis besser abschneiden als durchschnittlich gebildete, aber es konnte nicht gezeigt werden, dass Bildung ein Schutzfaktor für die kognitive Entwicklung über fünf Jahre ist. Die Resultate weisen jedoch darauf hin, dass kognitives Engagement eine unterstützende Funktion in Bezug auf die kognitive Leistung hat: Durchschnittlich gebildete Individuen, die über ein hohes Ausmass an

kognitivem Engagement berichteten, konnten im Bereich der Wahrnehmungsgeschwindigkeit mit der Leistung der hochgebildeten mithalten.

Studie 2 setzte sich damit auseinander, ob sechs verschiedene kognitive Fähigkeiten mit drei verschiedenen Persönlichkeitseigenschaften über vier Jahre zusammenhängen. Diese Studie basierte auf Längsschnittdaten von 236 älteren Erwachsenen. Im Allgemeinen wurden nur wenige und schwache Zusammenhänge zwischen den beiden Domänen gefunden:

Schlussfolgerndes Denken korrelierte vier Jahre später mit Offenheit und Gewissenhaftigkeit korrelierte vier Jahre später mit Verbalem Wissen. Es stellt sich die Frage, ob oder unter welchen Umständen kognitive Fähigkeiten (Maximalleistung) mit Persönlichkeitseigenschaften (typische Verhaltensweise) in Zusammenhang stehen.

Studie 3 testete, ob das Beschweren über kognitive Schwierigkeiten den Effekt von Kognition auf emotionale Stabilität über 12 Jahre medierte und umgekehrt, ob das Beschweren über kognitive Schwierigkeiten den Effekt von emotionaler Stabilität auf Kognition über 12 Jahre medierte. Diese Studie basierte auf Längsschnittdaten von 500 älteren Erwachsenen. Die Ergebnisse zeigen, dass das Beschweren über kognitive Schwierigkeiten den Effekt von Kognition auf emotionale Stabilität über 12 Jahre medierte, nicht aber in die umgekehrte Richtung. Aus den Ergebnissen lässt sich schliessen, dass kognitive Ressourcen ein Schutzfaktor für die emotionale Stabilität im Alter sein könnten.

Das Ziel von Studie 4 war, die täglichen Zusammenhänge zwischen (a) offenen Verhaltensweisen und kognitivem Engagement sowie (b) neurotischen Verhaltensweisen und dem Beschweren über kognitive Schwierigkeiten sowohl zwischen als auch innerhalb Personen (between-person und within-person) zu untersuchen. Studie 4 basierte auf sogenannten Ambulatory Assessment Daten („Alltagsdaten“) von 136 älteren Erwachsenen. Multilevel Analysen bestätigten die Hypothese, dass offene Verhaltensweisen und kognitives Engagement im Alltag auf beiden Analysestufen (between-person und within-person) positiv zusammenhängen. Hingegen wurde auf beiden Analysestufen kein signifikanter

Zusammenhang zwischen neurotischen Verhaltensweisen und dem Beschweren über kognitive Schwierigkeiten gefunden. Zukünftige Interventionsstudien sollten testen, ob eine einfache Intervention, die darauf abzielt, dass sich Individuen offener verhalten, auch deren kognitives Engagement erhöht.

Studie 5 (Pilotstudie) testete, ob es möglich ist, die Augenbewegungen von älteren Erwachsenen über einen Eyetracker in einem “Real-Life-Assessment-Paradigma” zu erfassen. Anschliessend war es von Interesse, ob es Zusammenhänge zwischen Persönlichkeitseigenschaften und diesen Augenbewegungen gibt. Studie 5 basierte auf Eyetracker-Daten von 38 älteren Erwachsenen, welche ihr Lebensmitteleinkauf getätigt und dabei einen Eyetracker getragen haben (“Real-Life-Assessment-Paradigma”). Studie 5 demonstrierte, dass es machbar ist, Augenbewegungen während des Einkaufens über einen Eyetracker zu erfassen. Dadurch gewährt diese Studie interessante Einblicke in die Eyetracker-Datenerfassung in einem alltäglichen Kontext und macht spezifische praktische Empfehlungen für zukünftige Studien.

Basierend auf den Ergebnissen der vorliegenden Dissertation ergeben sich drei Hauptimplikationen für zukünftige Forschung. Erstens, die Untersuchung von längsschnittlicher Entwicklung sollte mit der Untersuchung kurzzeitiger, dynamischer Prozessen vereinigt werden. Zweitens, Trainingselemente aus der kognitiven Psychologie und Persönlichkeitspsychologie sollten kombiniert werden, wenn individualisierte Interventionen für ältere Menschen entwickelt werden. Drittens, die Untersuchung von Zusammenhängen zwischen Kognition und Persönlichkeit sollte erweitert werden, um der lebenslänglichen und holistischen Perspektive des Gesunden Alterns gerecht zu werden.

Original Research Articles and Book Chapters Included in the Present Doctoral Thesis

Study 1:

Schumacher, V., Aschwanden, D., Zimmermann, K., Werner, C., Allemand, M., Zimprich, D., & Martin, M. (submitted in January 2018 to Psychological Science). *Are professors special? A five-year longitudinal study on cognitive development in old age.*

Study 2:

Aschwanden, D., Martin, M., & Allemand, M. (2017). Cognitive abilities and personality traits in old age across four years: More stability than change. *Journal of Research in Personality*, 70, 202–213. doi:10.1016/j.jrp.2017.08.002

Study 3:

Aschwanden, D., Kliegel, M., & Allemand, M. (in press). Cognitive complaints mediate the association between cognition and emotional stability across 12 years in old age. *Psychology and Aging.*

Study 4:

Aschwanden, D., Luchetti, M., & Allemand, M. (submitted in February 2018 to the Journal of Personality). *Personality-related behaviors are associated with cognitive engagement and cognitive complaints in daily life of older adults.*

Study 5:

Aschwanden, D., Langer, N., & Allemand, M. (submitted in February 2018 to Social Psychological and Personality Science). *Using eye tracking to assess personality manifestations in the wild? Piloting a real-life assessment paradigm.*

Extracts from Book Chapters:

Allemand, M., Aschwanden, D., Martin, A., & Gruenenfelder, A. E. (2017). Personality trait development in adulthood and old age. In J. Stein (Ed.), *Module in Neuroscience and Biobehavioral Psychology* (pp.1-8). San Diego, CA: Elsevier.

Aschwanden, D., Allemand, M., & Hill, P. L. (in press). Cognitive methods in personality research. In B. J. Carducci (Editor-in-Chief & Vol Ed.), *The Wiley-Blackwell encyclopedia of personality and individual differences: Vol. II. Research methods and assessment techniques*. Hoboken, NJ: John Wiley & Sons.

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1 Introduction

Aging is characterized by individual changes in various life domains such as health, cognition¹, and social environment. As life expectancy increases globally, a general demographic shift to older populations is indispensable in the near future (World Economic and Social Survey, 2007). From societal and economic viewpoints, it is thus highly relevant to promote functional independence, autonomy, and well-being in this growing group of population. An essential component with regard to these three factors is cognitive functioning as it can affect one's quality of life and the ability to live independently (Salthouse, 2004).

With increasing age, various cognitive abilities tend to decline. This phenomenon is also known as cognitive aging (Salthouse, 1991), and one of the most highly discussed health topics of the current century. Whereas fluid abilities begin to decline earlier, crystallized abilities appear to decrement in the late 70s (Schaie & Willis, 2010; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003). In cognitive aging research, three prominent theories are proposed to explain age-related cognitive decline. The *speed-hypothesis* (Salthouse, 1996) postulates that increased age is associated with a decrease in the speed with which many processing operations can be executed, thus leading to cognitive impairments. The *common-cause-hypothesis* (Baltes, & Lindenberger, 1997) states that age differences in cognitive and sensory domains are the outcome of a third common factor (i.e., the integrity of brain structure and function and its aging-induced changes). The *differentiation-dedifferentiation hypothesis* suggests that from childhood to early maturity, the structure of cognition changes from a general, unified ability to a set of abilities (Garrett, 1946), and the reverse phenomenon is postulated from early maturity to late adulthood (Balinsky, 1941). A number of empirical studies evidenced age-related decreases in cognitive abilities such as executive functions (Head, Kennedy, Rodrigue, & Raz, 2009), episodic memory (Buckner, 2004), reasoning (Singh-Manoux et al., 2012), processing speed (Eckert, 2011; Salthouse,

¹Note that in the following the terms cognition and cognitive abilities are used interchangeable. See section 1.2.1 for the underlying rationale and a definition of the terms.

1996), naming and verbal fluency (e.g., Albert, Heller, & Milberg, 1988) as well as visual and verbal memory (e.g., Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992).

However, the pattern of cognitive decline is neither linear nor consistent, and it is only loosely related to chronological age (Steves, Spector, & Jackson, 2012). This means, while some 75-years-olds may enjoy good cognitive and physical functioning, others might be frail or dependent on support from others to meet their basic needs. From the theoretical perspective of lifespan developmental psychology (Baltes, Lindenberger, & Staudinger, 2007), cognition is characterized by plasticity (i.e., intraindividual modifiableness), multidimensionality (i.e., it consists of different abilities such as memory or processing speed), and multidirectionality (i.e., the various abilities may show different developmental trajectories across the lifespan, however, there seems to be a rather unidirectional development in very old age [cf. Martin & Kliegel, 2008, p. 152]). As such, the adult brain is capable of life-long plasticity as a function of training or experience, meaning that brain anatomy and brain physiology change in response to cognitive challenges (Jäncke, 2009; Pascual-Leone, Amedi, Fregni, & Merabet, 2005). Moreover, older adults show substantial interindividual variability in the change and decline of different cognitive abilities (Wilson et al., 2002). Hence, the question emerges why some older individuals maintain or even improve their cognitive abilities, whereas others show cognitive decline as they age. In addition to the three afore-mentioned theories, a considerable amount of studies has identified several factors that can explain at least some of the variability in cognitive aging (see Daffner, 2010; Smith, 2016, for reviews, and Hill & Payne, 2017, for supplement). Briefly, cognitive aging is influenced by genetic, environmental, behavioral, social and socio-economic factors. As such, these factors can be broadly distinguished in two categories, that is biological and non-biological (cf. Nyberg & Bäckman, 2006). A recent example belonging to the biological category is functional connectivity in the resting state brain, where maintaining higher synchronous intrinsic functional connectivity protects for age-related decrease in processing

speed (Hirsiger et al., 2016). Two examples belonging to the non-biological category are education and personality²: Education is deemed to be one of the most prominent predictors of cognitive change - or stability, respectively, - in older age (Albert et al., 1995). Furthermore, recent perspectives on cognitive aging have identified the potential for different personality traits to also influence cognition into later life (Curtis, Windsor, & Soubelet, 2015). The present thesis focuses thus on education and personality traits. The overall goal of the current thesis is to gain a more elaborated picture about the role of education and personality traits in cognitive aging, whereas the emphasis is on the latter. Specifically, the aim is to provide new knowledge about the longitudinal associations between cognition and personality that contribute to healthy aging over years (long-term development) as well as over days (short-term dynamics processes). It is crucial to distinguish between different temporal perspectives such as long-term development and short-term dynamic processes in daily life, because long-term associations do not need to reflect short-term associations for the same variables (e.g., Bolger & Laurenceau, 2013; Hollenstein, Lichtwarck-Aschoff, & Potworowski, 2013). Therefore, the present thesis considers both aforementioned time perspectives.

1.1 Relevance of the Topic

It is important to untangle the role of education in cognitive aging, because this will contribute to our broader understanding of cognitive reserve and age-associated cognitive decline (Alley, Suthers, & Crimmins, 2007). Furthermore, understanding cognition-personality associations is important for several reasons. First, both cognition and personality are central concepts defining daily functioning in older age. Specific personality traits may either help older adults to maintain their cognitive functioning and performance as they age (Baker & Bichsel, 2006) or serve as a source of vulnerability concerning cognitive decline and impairment (Chapman et al., 2012; Terracciano, Stephan, Luchetti, Albanese, & Sutin,

²Note that in the following the terms personality and personality traits are used interchangeable. See section 1.2.2 for the underlying rationale and a definition of the terms.

2017). Conversely, it is also possible that cognitive functioning is a requisite condition for personality traits to remain stable or to change in older age (cf. Moutafi, Furnham, & Crump, 2003). Life-span developmental theory suggests that life-span dynamics of an increasingly negative gain-loss ratio in the cognitive and health domains (Baltes & Baltes, 1990) as well as declines in perceived control (Heckhausen & Schulz, 1995; Lachman, 2006) constitute key risk factors for personality development. As such, reduced cognitive reserve capacity can be expected to shape personality trait development later in life (Wagner, Ram, Smith, & Gerstorf, 2016). Knowing whether and which personality traits or cognitive abilities have maintenance functions for the respective domains may help to strengthen these particular personality traits and cognitive abilities, respectively. To illustrate, a study has shown that stability in neuroticism and openness (compared to change in either direction) was related to better reasoning performance and faster reaction time (Graham & Lachman, 2012). These findings suggest that maintaining a stable personality may be more beneficial than even socially desirable change (such as decline in neuroticism) for some variables. Briefly, the investigation of cognition-personality relations provides information about the basics (i.e., reciprocal influences) of the two domains.

Second, shedding light on the associations between cognition and personality traits can provide guidance for researchers to develop specific interventions such as cognitive interventions for different personality types (cf. Studer-Luethi, Jaeggi, Buschkuhl, & Perrig, 2012) or personality interventions depending on cognitive characteristics (cf. Jackson, Hill, Payne, Roberts, & Stine-Morrow, 2012; but see also Sander, Schmiedek, Brose, Wagner, & Specht, 2017). Furthermore, one could also think about combined cognitive-personality interventions (for example, possible ideas are discussed in Aschwanden, Kliegel, & Allemand, in press).

Third, the investigation of cognition-personality relations may lead to a better integration of the two domains in aging research. Briley and Tucker-Drob (2017) observed

that empirical studies of cognition and personality have tended to operate in isolation of one another and thus they suggested that considering cognition and personality collectively could enrich the understanding of human development. Furthermore, the integration of cognition and personality has remained largely unaddressed, particularly at the theoretical level (Chamorro-Premuzic & Furnham, 2004). Theories about cognition-personality relations exist sporadically in literature, for instance the “personality-intelligence interface” (Chamorro-Premuzic & Furnham, 2004), the “intelligence compensation hypothesis” (Moutafi et al., 2003), the “extraversion-crystallized intelligence hypothesis” (Stough et al., 1996), the “top-down approach” (Rindermann & Neubauer, 2001) or the “theory of intelligence as process, personality, interests and knowledge” (Ackerman, 1996). Nevertheless, there is no universal theory on the relationship between cognition and personality that is predominately used in the research field. Examining these relationships may, however, build a basis for integrating research findings and for developing a theoretical model to its full extent.

The overall structure of this thesis takes the form of five chapters, including this introductory chapter in which definitions of terms and concepts are given. Next, a brief overview of the aspired research aims and research questions is presented. Third, methodological considerations for studying these research questions are presented. The five empirical studies (Studies 1-5) included in this thesis are described in the fourth chapter. Finally, the overall findings and implications of the present thesis are discussed in the last chapter.

1.2 Definitions of Terms and Concepts

1.2.1 Cognition: Maximal Performance and Daily Behaviors

Cognition can be defined as “act or process of knowing or coming to know”, and describes the processes of thought (Kolb & Whishaw, 2006, p. 523). Cognitive abilities refer to the different abilities of the brain to process, retrieve, and store information (cf. Salkind, 2005, p. 29). For example, memory, processing speed, reasoning, verbal knowledge, verbal

learning, and working memory are such cognitive abilities (cf. Zimprich et al., 2008). In the laboratory, cognitive abilities are usually assessed by different cognitive tasks where individuals show what they are able to perform (maximal performance). Maximal performance can be measured using power tasks that increase in difficulty or speed tasks that need to be executed as fast and accurately as possible (cf. Weber, 2012, p. 35). In daily life, there is usually no need to perform at the maximum in order to manage one's daily duties. In contrast, individuals manage their daily life by engaging in different activities and behaviors (daily behaviors). Indeed, these activities and behaviors require some cognitive effort, but usually individuals are not at their cognitive limit while performing them. In current literature, there are three approaches to capture cognitive performance and cognitive behaviors in daily life. First, cognitive tasks from the laboratory can be solved in daily life. For instance, participants are asked to solve different working memory tasks via smartphones several times a day in a working memory training (e.g., Könen, Dirk, & Schmiedek, 2015). As a result, daily fluctuations in working memory performance can be assessed. Second, cognitive tasks from daily life can be solved in the laboratory. For example, participants are required to hide daily life objects (such as an earring, a spoon, or a coin) and to recall them later in the "what-where-when memory task" (e.g., Mazurek, Bhoopathy, Read, Gallagher, & Smulders, 2015). As such, memory performance of familiar objects can be measured. Whereas both of these approaches focus on maximal performance in different contexts, the last approach puts its emphasis on everyday behaviors. Namely, cognitive activities and behaviors such as cognitive engagement or cognitive complaints can be assessed both in the laboratory (e.g., Kliegel & Zimprich, 2005) and in daily life (e.g., Aschwanden, Luchetti, & Allemand, manuscript submitted). As an outcome, self-, or other reported activities and behaviors can be obtained.

Previous research has observed a strong disconnect between cognition assessed in the laboratory versus in daily life: On the one hand, laboratory-based studies generally report age-related decline in cognitive abilities, but on the other hand, simple observations in the wild

suggest that older adults, generally speaking, do very well in their daily life (e.g., Bielak, Hatt, & Diehl, 2017; Blanchard-Fields, 2007; Hertzog, Kramer, Wilson, & Lindenberger, 2008; Verhaeghen, Martin, & Sedek, 2012). A possible explanation for this observed disconnection may be that indeed adults decline in their maximal cognitive performance with age, the orchestration of compensatory mechanisms and strategies may help them to manage their daily life without showing maximal performance. This disconnection highlights that phenomena demonstrated in the laboratory may not actually occur in the real world (Bolger & Laurenceau, 2013) or in other words, the correlation between laboratory and daily life outcomes may not always be strong (Wrzus & Mehl, 2015). Therefore, it makes sense to study cognition and other psychological phenomena in the context of both laboratory and daily life. In this thesis, both contexts are considered.

Furthermore, the terms cognition, cognitive abilities, and cognitive behaviors are used in the current work. In the introduction and discussion, the term cognition is used for the sake of simplicity whenever there is no need to emphasize the multidimensionality of cognition or to differentiate between specific cognitive abilities, respectively. In this sense, cognition is used as an umbrella term for different cognitive abilities. Moreover, Study 1 and Study 2 relied on maximal performance of different cognitive abilities (see the corresponding sections for what cognitive abilities were measured). In addition, Study 1 involved self-reported cognitive behaviors (i.e., cognitive engagement) that were assessed in the laboratory. Study 3 referred to maximal performance of general cognition (see the corresponding section for which cognitive tasks were used) and cognitive behaviors (i.e., cognitive complaints) that were measured in the laboratory. Study 4 examined cognitive behaviors (i.e., cognitive engagement and cognitive complaints) that were assessed in daily life. Study 5 (feasibility study) did not focus on cognitive measures.

1.2.2 Personality³: The Big Five in the Laboratory and in Daily Life

Personality can be defined as “psychological qualities that contribute to an individual’s enduring and distinctive patterns of thinking, feeling and behaving” (Cervone & Pervin, 2009, p. 8). In other words, personality is referred to individual differences in characteristic patterns of behavior, thoughts, and feelings. These individual differences can be described as traits, and they are relatively stable across various situations and contexts (Allemand & Hill, 2017), but they also refer to other aspects of multiple life domains such as goals, values or life stories (McAdams & Olson, 2010; Roberts & Wood, 2006). Personality traits can be organized in a conceptual framework that consists of five basic trait clusters, the so-called Big Five (e.g., Goldberg, 1990; John & Srivastava 1999) or Five-Factor model (e.g., McCrae & John, 1992; McCrae & Costa, 1999; John, Naumann, & Soto, 2008). Referring to Costa and McCrae’s (1992b) terminology, the five factors may be labeled (1) neuroticism, (2) extraversion, (3) openness to experience, (4) agreeableness, and (5) conscientiousness. Briefly, neuroticism, or conversely, emotional stability contrasts even-temperedness with the experience of anxiety, worry, anger, and depression. Extraversion refers to individual differences in the propensity to be sociable, active, assertive, and to experience positive affect. Openness to experience (hereafter openness) refers to individual differences in the proneness to be original, complex, creative, and open to new ideas. Agreeableness refers to traits that reflect individual differences in the propensity to be altruistic, trusting, modest, and warm. Finally, conscientiousness reflects the propensity to be self-controlled, task- and goal-directed, planful, and rule-following.

³Parts of this section have been published as a book chapter in *Module in Neuroscience and Biobehavioral Psychology* (Copyright notice: Elsevier). This section does not exactly replicate the original version. It is not the copy of record. Original book chapter published by Elsevier:

Allemand, M., Aschwanden, D., Martin, A., & Gruenenfelder, A. E. (2017). Personality trait development in adulthood and old age. In J. Stein (Ed.), *Module in Neuroscience and Biobehavioral Psychology* (pp.1-8). San Diego, CA: Elsevier.

In the laboratory, personality traits are predominantly measured by questionnaires where individuals describe their behaviors and attitudes, but they can also be assessed by behavioral observations or physiological assessment. In daily life settings, these three approaches can be used too. First, personality can be captured by self-reports that are provided once or multiple times per day using mobile phones (Mehl & Connor, 2012). Second, behavioral observations can be obtained by observer-reports, but also via external or mobile phone sensors that collect environmental or device-usage information such as audio, visual, GPS and user logs (Wrzus, & Mehl, 2015). The aggregated features obtained from mobile phone data can be used as indicators of the Big Five personality traits as demonstrated by Chittaranjan, Blom, and Gatica-Perez (2011). The authors found that the usage of diverse mobile phone applications significantly explained variance in the Big Five traits. For example, the mail application was more likely to be used by neurotic and conscientious participants, whereas extraverts and agreeable individuals were likely to receive more calls. Third, external or mobile phone sensors can collect physiological data (e.g. cardiac, electrodermal, physical, muscle or cortical activity) in daily life. It is conceivable that these data will be combined with self-report measures in the near future (Wilhelm, Grossman, & Müller, 2012). Similar to behavioral observations, aggregated physiological features could serve as indicators of different personality traits.

Similar to cognitive measures, laboratory and daily life assessments of personality may not always correspond strongly (Wrzus & Mehl, 2015). This correlation may be low for several reasons. For instance, situational factors such as being unusually quiet or talkative on a certain day or even time of day (e.g., Fleeson, 2001) affect laboratory assessments more strongly than daily life assessments, because the laboratory assessments often occur only once over a time period. In contrast, situational factors are assumed to vary and level out over a daily life assessment period. Furthermore, it may also be that some people follow the salient norms or expectations more strongly in the laboratory than in their daily life (Wrzus & Mehl,

2015). However, as stated by Wrzus and Mehl, discrepancies are often theoretically informative as they point to potential moderators of the studied association.

In the current thesis, the terms personality, personality traits (i.e., Big Five), and personality behaviors are used. In the introduction and discussion, the term personality is used for the sake of parsimony whenever there is no need to emphasize the multidimensionality of personality or to differentiate between specific traits, respectively. Study 2, Study 3, and Study 5 (feasibility study) relied on self-reported personality traits (see the corresponding sections for what traits were measured) that were conducted in the laboratory. Study 4 referred to self-reported behaviors related to personality (openness and neuroticism) that were assessed in daily life. Study 1 did not focus on personality measures.

1.2.3 Healthy Aging

Healthy aging is a commonly used term in academia and politics, yet there is little consensus on its definition (see Peel, Bartlett, & McClure, 2004, for a review). While a variety of definitions has been suggested, this thesis uses the definition of the World Health Organization (WHO). The WHO defines healthy aging in its world report on aging and health “as the process of developing and maintaining the functional ability that enables well-being in older age” (2015, p. 28). Well-being is broadly defined as “it includes happiness, satisfaction, and fulfilment” (p. 29). According to the above-mentioned WHO report, functional ability contains all health-related attributes that facilitate individuals “to be and to do what they have reason to value” (p. 28). Although these beings and doings may differ between as well as within individuals over time (Carstensen, Isaacowitz, & Charles, 1999; Carstensen et al., 2011), some examples of them are the following: a role or identity, relationships, the possibility of enjoyment, autonomy, security, and the potential for personal growth (e.g., Bowling & Dieppe, 2005; Grewal et al., 2006). Healthy aging is conceptualized as a dynamic process that starts at birth with genetic inheritance. Across the lifespan, healthy aging is

influenced by personal characteristics (e.g., ethnicity, occupation, education, personality) and health characteristics (e.g., physiological risk factors, diseases, health-related behaviors).

Both long-term development change and short-term dynamic processes may contribute to healthy aging. For example, cognitive decline and/or a decrease in conscientiousness over years (long-term development) as well as daily cognitive complaints and/or daily neurotic behaviors (short-term dynamic processes) may negatively influence healthy aging, but cognitive stability and/or an increase in openness over years (long-term development) as well as daily cognitive stimulation and/or conscientious behaviors (short-term dynamic processes) may positively contribute to healthy aging. Whereas developmental changes may be observable only across months or years, short-term dynamic processes may transpire on a day-to-day or moment-to-moment basis (Sliwinski, 2008).

Furthermore, there may be various ways how cognition-personality relations contribute to healthy aging. First, the mere level-level relations could influence healthy aging. For instance, high levels of both cognitive functioning and openness may be a better prerequisite to enable well-being than low levels of these domains. Second, the cognition-personality relations may contribute to healthy aging through various mechanisms such as health behaviors (e.g., nutrition) or cognitive behaviors (e.g., cognitive engagement). For example, individual differences in personality traits may be related to differences in how, when and why individuals engage in cognitive behaviors (i.e., cognitive engagement). To be more specific, people who are interested in reading activities might read more often than others, thus maintaining specific cognitive abilities and acquiring new knowledge compared to individuals who do not like reading books and newspapers. Consequently, these individuals might not only show better reading performance and/or general knowledge, but they may also feel happy, satisfied and fulfilled. Put simply, they age healthily.

The present thesis investigated the longitudinal associations between cognition and personality that contribute to healthy aging over years (Studies 1-3) and over days (Study 4).

Furthermore, Study 4 focused on the stabilization (Martin, Jäncke & Röcke, 2012) of health characteristics (behaviors related to cognition and personality). Stabilization is defined as “a dynamic process unfolding within individuals over time” (Martin et al., 2012, p. 185), and refers to intraindividual adaption and regulation processes (in contrast to stability which is usually examined as outcome). Hence, Study 4 examined the dynamic associations between (a) open behaviors and cognitive engagement, and (b) neurotic behaviors and cognitive complaints within individuals over ten days. Whereas Studies 1-3 answer questions on interindividual differences in long-term changes, and therefore, stability or instability of the outcomes targeted, Study 4 gives insights into intraindividual stabilization behaviors.

2 Aims and Research Questions

The current thesis pursued three main research aims by answering five open research questions. The first goal was to gain a more elaborated picture about possible differences in cognitive aging due to education (Study 1). The second goal was to shed light on the longitudinal associations between cognition and personality, thereby moving from long-term development to short-term dynamics processes in daily life. Although there is some empirical evidence for cross-sectional and longitudinal associations between cognition and personality (see Curtis et al., 2015, for a review; and Luchetti, Terracciano, Stephan, & Sutin, 2016, for a meta-analysis), less is known about these relations (a) over years (long-term development), (b) possible underlying mechanisms in the long-term development (mediators), and (c) over days (short-term dynamic processes). The centerpiece of the present thesis was to address these research gaps with three different empirical studies (Studies 2-4). The last goal was to innovatively test grocery shopping as a real-life assessment paradigm with older adults and to explore possible links between personality traits and eye movements (Study 5). Figure 1 displays a graphical overview of the studies included in the present thesis. All studies consisted of samples in late adulthood, the third or the fourth age (Baltes, & Smith, 2003). The age ranges varied from 65-80 years (Studies 1-2), 60-64 years (Study 3), 60-91 years (Study 4), and 59-87 years (Study 5) at baseline assessments. In the following, the open research questions are presented accompanied by a brief overview of the studies.

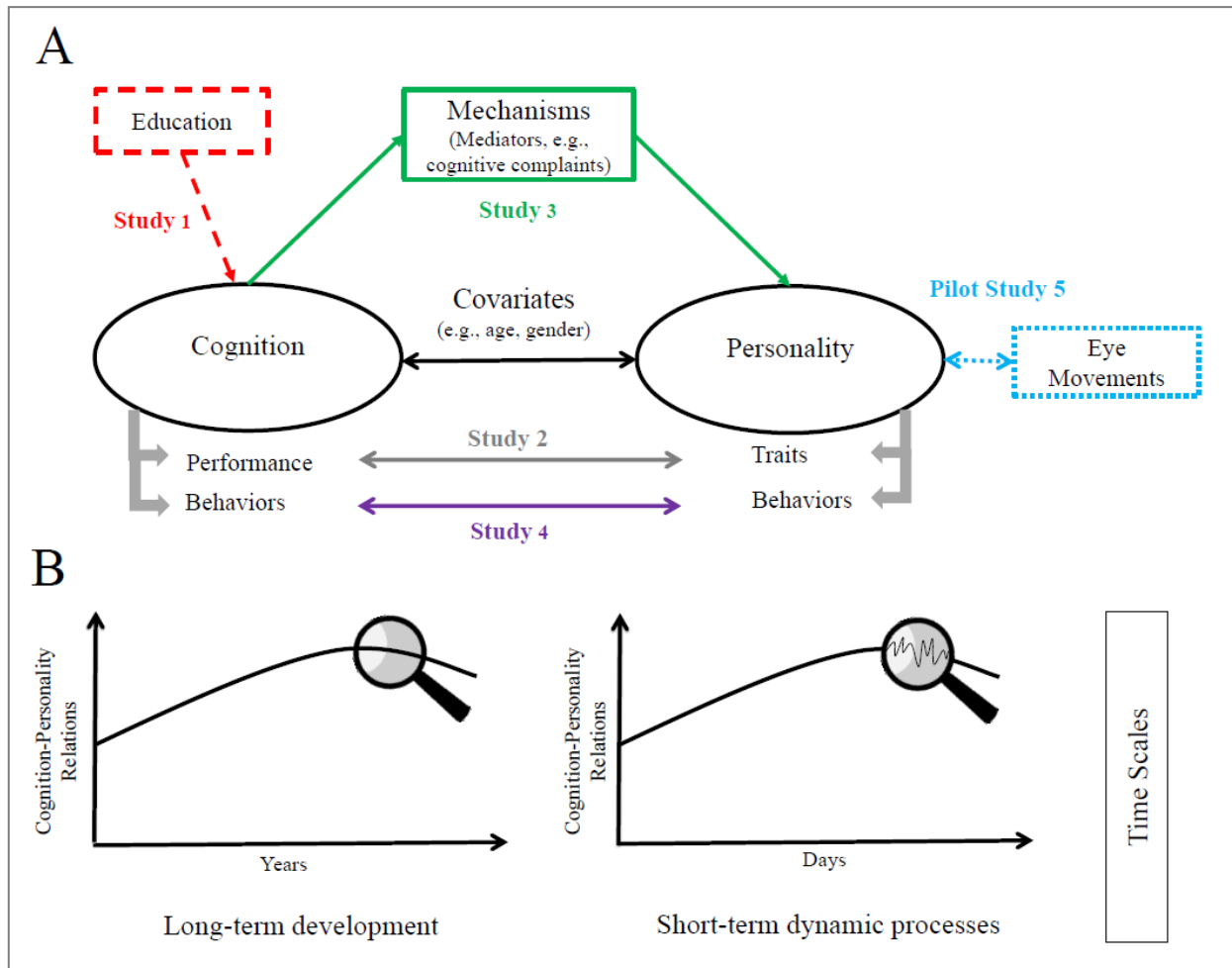


Figure 1. *Graphical Overview of the Empirical Studies*

Notes. The overall goal of the current thesis was to examine the longitudinal associations between cognition and personality that contribute to healthy aging over years and days. Part A shows the studies included in this thesis. Study 1 examined the role of education in cognitive aging. Study 2 investigated the cross-lagged relations between cognitive abilities and personality traits. Study 3 tested the mediating effect of cognitive complaints between cognition and emotional stability. Study 4 shed light on the daily links between behaviors related to cognition and personality. Study 5 (feasibility study) explored possible relations between personality and eye movements in a real-life assessment paradigm. As illustrated by the timescales (adapted from Nesselroade, 1991) in Part B, there was a shift from long-term longitudinal development (Studies 1-3) to short-term dynamic processes (Studies 4-5).

Research Question 1: What is the role of education in cognitive aging? Are there differences of cognitive development across five years between highly and averagely educated individuals?

Although it is assumed that higher education is protective against cognitive decline (e.g., Leibovici, Ritchie, Ledéser, Touchon, 1996; Schaie, 1989), studies investigating the cognitive development of highly educated individuals (i.e., professors) are limited. The purpose of Study 1 was to compare cognitive development across five years between highly educated individuals (mean of education: 20.78 years) and averagely educated individuals (mean of education: 13.11 years). Study 1 was based on longitudinal data from two different samples, that is a highly educated sample (i.e., professors, $N = 39$) from the Zurich Longitudinal Study on Cognitive Health (Schumacher & Martin, 2009), and an averagely educated sample ($N = 236$) from the Zurich Longitudinal Study on Cognitive Aging (ZULU; Zimprich et al., 2008). Both samples performed the same cognitive test battery measuring episodic memory, working memory, and perceptual speed at two measurement occasions. The main analyses were based on mixed analyses of variances (ANOVAs) on trimmed means (Wilcox, 2012) to account for the differences in sample size, investigating if there is an interaction between education groups (between-subjects) and time (within-subjects) on episodic memory, working memory, and perceptual speed.

Research Question 2: How are levels of different cognitive abilities related to levels of different personality traits four years later?

Previous research has shown primarily cross-sectional and sometimes inconsistent links between different cognitive abilities and different personality traits (Ashton, Lee, Vernon, & Jang, 2000; Baker & Bichsel, 2006; Gignac, Stough, & Loukomitis, 2004; Soubelet & Salthouse, 2011; Zimprich, Allemand, & Dellenbach, 2009). The most consistent associations were found for openness and neuroticism, whereas openness is

positively related to measures of cognitive abilities, and neuroticism is negatively associated with measures of cognitive abilities (e.g., Baker & Bichsel, 2006; Graham & Lachman, 2012; Schaie, Willis, & Caskie, 2004; Soubelet & Salthouse, 2011). However, less is known about the longitudinal associations between cognitive abilities and personality traits in older age (e.g., Curtis et al., 2015). Study 2 thus examined the longitudinal associations between cognitive abilities (memory, processing speed, reasoning, verbal knowledge, verbal learning, and working memory) and personality traits (openness, neuroticism, and conscientiousness) in terms of cross-lagged effects. Study 2 was based on longitudinal data ($N = 236$) coming from the Zurich Longitudinal Study on Cognitive Aging (ZULU; Zimprich et al., 2008). The main analyses were based on bivariate autoregressive and cross-lagged regression models in the context of longitudinal structural equation modeling (SEM). In addition, Study 2 was designed to investigate research questions regarding the two domains' stability and change that are presented in the fourth chapter (see section 4.2.1).

Research Question 3: What is the role of cognitive complaints in the longitudinal association between cognition and emotional stability?

The existing literature supports a positive relationship between cognition and emotional stability (e.g., Arbuckle, Gold, & Andres, 1986; Gow, Whiteman, Pattie, & Deary, 2005), but information about the mechanisms that underlie this association is lacking (cf. Curtis et al., 2015; Wettstein, Kuźma, Wahl, & Heyl, 2016). Study 3 investigated cognitive complaints as a possible mediator of the bidirectional longitudinal association between cognition and emotional stability in older age. Study 3 was based on longitudinal data across three measurement occasions over 12 years. The study sample consisted of 500 older individuals from the Interdisciplinary Longitudinal Study on Adult

Development (Sattler et al., 2015). The main analyses were based on longitudinal mediation models in the context of structural equation modeling (SEM).

Research Question 4: (A) How is cognitive engagement related to open behaviors at the daily between- and within-person level? (B) How are cognitive complaints related to neurotic behaviors at the daily between- and within-person level?

Previous studies have established positive relationships between both openness and cognitive engagement as well as between neuroticism and cognitive complaints at the between-person level (e.g., Ackerman & Goff, 1994; Kliegel & Zimprich, 2005; Lane & Zelinski, 2003; Soubelet & Salthouse, 2010). In contrast to the between-person level, there is much less information about these associations at the within-person level in daily life. Study 4 aimed to investigate the daily associations between (a) open behaviors and cognitive engagement as well as (b) neurotic behaviors and cognitive complaints at both levels of analysis (between-person and within-person). The sample consisted of 136 healthy older participants from the RHYTHM (Realizing Healthy Years Through Health Maintenance) study. The main analyses were based on conditional random-intercept-random-slope models in the context of multilevel modeling (MLM).

Research Question 5: (A) Is it possible to successfully record and evaluate eye movements of older adults during grocery shopping? (B) If so, are there associations between different personality traits and eye movements?

Eye movements are assessed via eye tracking that has become an important method in different areas of psychology such as cognitive, neuropsychological, developmental and personality science (e.g., Duchowski, 2002; Rayner, 1998, 2009). Several aspects of eye movements behaviors (e.g., number of fixations, fixation duration) have been used to study various cognitive processes such as attention or perception

(Eckstein, Guerra-Carrillo, Miller Singley, & Bunge, 2017). Though, eye movements have not only been linked to cognition, but also to personality. Data from several studies suggest that individual differences in personality are related to eye movements of young adults in the laboratory (e.g., Matsumoto, Shibata, Seiji, Mori, & Shioe, 2010; Nitzschner, Nagler, Rauthmann, Steger, & Furtner, 2015; Risko, Anderson, Lanthier, & Kingstone, 2012). Nevertheless, far too little attention has been paid to these associations in real life and in older age, indicating a need to understand these relations of older adults beyond laboratory tasks. Primarily, there seems to be no paradigm to assess eye movements of older adults in real life. Hence, Study 5 piloted the feasibility of a real-life assessment paradigm (grocery shopping) with older adults. Furthermore, possible links between personality traits and eye movements were explored. Participants ($N = 38$) came from the pilot project “Big Five Shopping Eye Tracker Study (B5-SES)”. The analyses were based on Spearman correlations.

3 Methodological Considerations

The current thesis is based on (a) longitudinal, (b) intensive longitudinal (ambulatory assessment), and (c) very intensive longitudinal (eye tracker) data. Longitudinal data were used to investigate long-term development (Studies 1-3), whereas ambulatory assessment and eye tracker data were used to examine short-term dynamic processes in daily life (Studies 4-5). In the following, the conceptual consideration of the temporal shift from long-term development to short-term dynamic processes in daily life as well as the statistical models that were applied are briefly introduced.

3.1 From Long-Term Development to Short-Term Dynamic Processes in Daily Life

The current thesis focused on two temporal aspects: The *long-term development* refers to a time scale of *years*, whereas the *short-term dynamic processes in daily life* rely on a time scale of *days* and *minutes*. Study 1 investigated a time interval of five years, Study 2 focused on a time interval of four years. Study 3 examined a time interval of 12 years. Study 4 investigated a time interval of ten days, whereas Study 5 (feasibility study) focused on minutes in a specific situation (i.e., grocery shopping).

Investigating long-term development provides important insights into developmental trajectories and interindividual variability in intraindividual change (Nesselroade & Baltes, 1974; Schaie & Hofer, 2001). Studying short-term dynamic processes in daily life is relevant because the variables of interest and their temporal unfolding can be examined in their natural, spontaneous context (Bolger & Laurenceau, 2013). These two temporal aspects do not only differ with regard to their time scale, but also in terms of the research setting. The long-term development of variables is usually assessed in the laboratory, while short-term dynamic processes are assessed in a real-life setting. Typically, short-term dynamics processes as they unfold naturally cannot be covered in laboratory studies (cf. Bolger, Davis, & Rafaeli, 2003; Reis & Gable, 2000). It is important to consider both temporal perspectives, because they answer different yet related research questions. Furthermore, associations found

in the laboratory may not actually occur in the real world (Bolger & Laurenceau, 2013). For example, the association between cognition and personality over years does not need to reflect the association between cognition and personality in daily life. Hence, the present thesis investigates these associations from long-term development (Studies 1-3) to short-term dynamic processes (Studies 4-5).

3.2 Statistical Methods

In order to analyze long-term development, mixed ANOVAs on trimmed means (Wilcox, 2012) and two models based on structural equation modeling (SEM; Little, 2013) were applied. For analyzing short-term dynamic processes, multilevel modeling (MLM; Bolger & Laurenceau, 2013; Raudenbush & Bryk, 2002; Singer & Willett, 2003) and simple Spearman correlations (Spearman, 1904) were used. In the following, these statistical methods are briefly introduced.

3.2.1 Mixed ANOVA on Trimmed Means

To test for differences amongst the cognitive performance of highly and averagely educated older adults at two measurement occasions (Study 1), mixed analyses of variance (ANOVAs) with the group variable (education) as between-subject factor and time (repeated cognitive performance) as within-factor were used. Given that the sample sizes of the two groups differed, mixed ANOVAs on trimmed means (Wilcox, 2012) were considered. The standard error of the trimmed mean is less affected by deviations from normality and sphericity than the normal mean because extreme observations (i.e., in the tail of a distribution) are censored or removed (Keselman, Algina, Wilcox, & Kowa, 2000). In additional analyses, analyses of covariance (ANCOVAs) with robust estimators (Field, Miles, & Field, 2012) were calculated.

3.2.2 Autoregressive Cross-Lagged Regression Model (based on SEM)

To examine how levels of different cognitive abilities were related to levels of different personality traits four years later (Study 2), autoregressive cross-lagged regression

models (Jöreskog, Sörbom, & Magidson, 1979; Kenny, 1975; McArdle, 2009) were used (hereafter cross-lagged models). These models allow for the simultaneous examination of the reciprocal associations between two variables (A, B) while controlling for previous levels of the outcome of interest (A_1 or B_1). The aim of these models is to explain the amount of variance due to cross-lagged effects ($A_1 \rightarrow B_2$) that is not explained by the stability of B ($B_1 \rightarrow B_2$). Overall, cross-lagged models allow the estimation of initial correlations (A_1, B_1), change correlations (or more precisely, correlations between residuals / A_2, B_2), the cross-lagged paths relating to A by previous levels of B ($B_1 \rightarrow A_2$), and cross-lagged paths relating to B by previous levels of A ($A_1 \rightarrow B_2$). As mentioned in the second chapter, there is evidence for associations between cognitive abilities and personality traits, but these relations are rarely analyzed reciprocally because previous research tended to focus on personality traits as predictors of cognitive abilities (cf. Curtis et al. 2015, Wettstein et al., 2016). Cross-lagged models allow to test whether levels of personality traits are predicted by levels of cognitive abilities and vice versa.

3.2.3 Longitudinal Mediation Model (based on SEM)

To test whether cognitive complaints mediated the effect of cognition on emotional stability and vice versa over 12 years (Study 3), longitudinal mediation models were applied. These models account for the temporal structure that is required to test mediation (cf. MacKinnon, Fairchild, & Fritz, 2007). This means, the mediator cannot be concurrent with the predictor and must precede the outcome (Lindenberger, von Oertzen, Ghisletta, & Hertzog, 2011; MacKinnon et al., 2007). In contrast, cross-sectional mediation models are unable to do so and can thus inflate the estimates of mediation (Maxwell & Cole, 2007). Moreover, longitudinal mediation designs allow to control for the most ubiquitous possible confounders, that is prior levels of the dependent and mediator variable (Cole & Maxwell, 2003; Gollob & Reichardt, 1991). This is important because mediation models make theoretical claims about causality, therefore, they require causally unbiased effects (e.g., Cole

& Maxwell, 2003; Judd & Kenny, 1981). To benefit from the advantage of longitudinal mediation, Study 3 fully met its requirements and used data from the first measurement occasion for the predictor variable, data from the second measurement occasion for the mediator variable, and data from the third measurement occasion for the outcome variable.

3.2.4 Random-Intercept-Random-Slope Model (based on MLM)

To examine the daily associations between (a) open behaviors and cognitive engagement as well as (b) neurotic behaviors and cognitive complaints (Study 4), conditional random-intercept-random-slope models (Raudenbush & Bryk, 2002) were used. These models allow to differentiate between within-person and between-person associations. Furthermore, it is possible to estimate within-person associations between the variables of interest for each individual, taking into account the potentially different intercepts and slopes of each participant due to environmental and individual influences (cf. Bolger & Laurenceau, 2013; Nezlek, 2011). As such, the inclusion of random intercepts permits the modeling of individual differences in the mean levels of the variables of interest around the intercept fixed effects. Likewise, the inclusion of random slopes permits the modeling of individual differences in the strength and direction around the fixed effects.

3.2.5 Spearman Rank Correlation

Spearman rank correlation coefficients (Spearman, 1904) were calculated to explore possible associations between different personality traits and eye movements (i.e., number of fixations on three areas of interest; Study 5). These coefficients are a non-parametric statistic based on ranked data. In contrast, the Pearson product-moment correlation coefficients (Pearson, 1896) are a parametric statistic, assuming the variables' approximate multivariate normal distribution. Whereas Spearman correlations describe the degree of monotonicity between two vectors of data, Pearson correlations measure their degree of linearity (de Winter, Gosling, & Potter, 2016). Given the data structure of Study 5 (feasibility study), Spearman correlations that minimize the effects of violations of the normal distribution

assumptions were used. For this purpose, Spearman correlations rank the data, that is, finding the lowest score and giving it a rank of 1, then finding the next highest score and giving it a rank of 2, and so on (Field, 2013). This procedure results in high scores being represented by large ranks, and low scores being represented by small ranks. The analyses are then carried out on these ranks.

4 Empirical Studies

4.1 Study 1: The Effect of Education on Long-Term Cognitive Development⁴

4.1.1 Introduction

Most cognitive abilities tend to decline in older age. Previous studies investigating cognitive abilities in older adults demonstrate significant decreases in test performance including visual and verbal memory (Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992), naming and verbal fluency (Albert, Heller, & Milberg, 1988) as well as fluid intelligence (Botwinick & Siegler, 1980). Although one could assume that age is the most prominent cause of the decrease of cognition in older adults, there is growing evidence that age only plays a subordinate role. There are currently two different research directions in cognitive aging research. One research direction investigates risk factors that may negatively affect cognitive development, such as high blood pressure, cardiovascular as well as cerebrovascular disease or the presence of apolipoprotein E (APOE; Anstey & Christensen, 2000). The other direction concentrates on buffers which help to stabilize or increase cognition in older age, such as education (Colsher & Wallace, 1991; Evans et al., 1993; Schaie, 1990), exercise, non-smoking or volunteering (Yaffe et al., 2009). In this paper, we pursue the second direction, focusing primarily on education as a protective factor against cognitive ability decline.

So far, educational history has been the most prominent non-biological predictor of cognitive change in older age (Albert et al., 1995). Individuals with a higher level of education demonstrate less age-related cognitive decline (Leibovici, Ritchie, Ledésert, & Touchon, 1996; Schaie, 1989; Williams & Kemper, 2010). For example, Leibovici and colleagues stated that education has greater effects on the development of episodic memory

⁴A similar version of this study has been submitted to *Psychological Science*. This chapter may not exactly replicate the submitted version. It is not the copy of record. Original article: Schumacher, V., Aschwanden, D., Zimmermann, K., Werner, C., Allemand, M., Zimprich, D., & Martin, M. (submitted). *Are professors special? A five-year longitudinal study on cognitive development in old age.*

and language functions than age. These effects seem to be independent of age, birthplace, language, occupation or income (Evans et al., 1993). A further study analyzing the effect of childhood education on cognitive abilities in older age found that changing the minimum school-leaving age in the United Kingdom from 14 to 15 years of age significantly affected memory and executive functioning of older males, even 60 years after graduation (Banks & Mazzonna, 2012). Moreover, Farmer, Kittner, Rae, Bartko, and Regier (1995) found that education was a significant predictor of cognitive decline even in younger individuals (<65 years), not only in older adults (>65 years).

One approach to measure the influence of education on cognitive development in older age is to test the cognitive abilities of an average group of people, analyzing the relationship between education and cognition. To ensure that effects of education are detectable, however, a very large sample is necessary. Another approach is to compare a highly selective sample, that is a highly educated sample, to an averagely educated comparison group. Excellent examples of individuals with extremely high education and lifelong cognitive engagement are professors. However, only few studies have examined the cognitive development of academics or professors so far, and these papers usually report controversial results (Christensen, Henderson, Griffiths, & Levings, 1997; Compton, Bachman, Brand, & Avet, 2000; Schumacher & Martin, 2009; Shimamura, Berry, Mangels, Rusting, & Jurica, 1995). Whereas cross-sectional studies (Compton et al., 2000; Schumacher & Martin, 2009; Shimamura et al., 1995) demonstrate better cognitive task performances and smaller age effects of highly educated individuals compared to averagely or lower educated individuals, longitudinal findings (Christensen et al., 1997) indicate that highly educated individuals do not differ in cognitive development compared to lower educated individuals. Shimamura and co-workers (1995), for example, compared cognitive test performance of professors of different age groups to the one of averagely educated people. The results indicated that, unlike the averagely educated people, the professors did not demonstrate age effects on measures of

proactive interference and prose recall. However, similar age effects occurred in reaction time, some aspects of working memory, and the error rate in paired associated learning. Another cross-sectional comparison by Compton et al. (2000) suggests that education, coupled with continued intellectual activity, may offset some of the cognitive declines usually associated with aging. Their sample of 102 members of professional and college communities were divided into four age groups (young, middle, late middle, older), in order to investigate age-associated changes in cognitive function (Wechsler Adult Intelligence Scales – Revised [WAIS-R], Wisconsin Card Sorting Test [WCST], Trail Making Test [TMT] A and B). Age appeared to be relevant in some of the neuropsychological measures including the assessment of perceptual and psychomotor speed (i.e., TMT A and B). Nevertheless, no age differences were detected on the WAIS-R. Similar findings were found by Schumacher and Martin (2009) comparing a sample of averagely educated individuals and highly educated retired professors. The cross-sectional comparison demonstrated a significantly better performance of the professors in the paired-associates learning and reading span test. Furthermore, the professors not only outperformed their comparison group in the test of paired-associates learning, their test performance increased with advancing age, whereas the one of the comparison group decreased with increasing age.

In contrast to the cross-sectional research described above, Christensen et al. (1997) found no evidence that academics demonstrate slower decline in their cognitive abilities than blue-collar workers over a period of five years. Nevertheless, these results must be considered against some methodical difficulties such as high drop-out rates (academics: 27%, blue-collar workers: 47%) and small sample size at wave 2 (academics: 22, blue-collar workers: 16) (cf. Zahodne, Stern, & Manly, 2015).

Reasons for inconsistent findings in literature could be the nature of the samples examined (professors vs. PhD students), different study designs, the influence of individual lifestyles, and differences in cognitive activity (Schumacher & Martin, 2009). Therefore, the

present study focuses on cognitive performance of highly educated retired professors in a longitudinal setting considering additional factors such as subjective health as well as cognitive engagement (TIE), to examine the role of education on cognitive development in older age. We hypothesize that the findings demonstrate smaller age-related differences in the professor sample, with education protecting against cognitive decline, and helping to stabilize cognitive performance over time. To test this hypothesis, data of the Zurich Longitudinal Study on Cognitive Aging (ZULU; Zimprich et al., 2008) including averagely educated individuals and the Zurich Longitudinal Study on Cognitive Health (Schumacher & Martin, 2009) including highly educated individuals were compared with each other.

4.1.2 Methods

Participants

Two samples of older adults with different educational background were compared in this study. The 236 participants of the averagely educated sample were either randomly chosen by the register of births, deaths and marriages of the city of Zurich or recruited from the Zurich University senior citizen lecture series ($M_{\text{age}} = 72.7$ years, 55.1% male). The addresses of the 39 participants of the highly educated sample were from the register of retired professors of the University of Zurich ($M_{\text{age}} = 72.9$ years, 95.1% male). While data of the averagely educated sample originated from the Zurich Longitudinal Study on Cognitive Aging (ZULU) which had been conducted in 2005, 2006 and 2010 (Zimprich et al., 2008), data acquisition of the highly educated sample of the Zurich Longitudinal Study on Cognitive Health took place in 2006 and 2011 (Schumacher & Martin, 2009). To analyze equal time intervals between the two groups, we focus on the ZULU measurement occasions of 2005 and 2010. As from now, it is referred to the two measurement occasions as T1 (ZULU: 2005 / professors: 2006) and T2 (ZULU: 2010 / professors: 2011). Furthermore, the findings in this article are based explicitly on individuals who completed both measurement occasions.

To test for attrition effects in each sample, dropouts who only participated at T1 (or from whom no data on the variables of interest at T2 exist) were compared with continuers who participated at both measurement occasions (T1 and T2). In the averagely educated sample, continuers ($n = 236$, 65.0%) were slightly healthier ($d = .36$) and performed better in three cognitive tasks (letter digit substitution: $d = .36$; paired associates: $d = .40$; reading span: $d = .30$) than dropouts ($n = 128$). Although these differences reflect small effects (Cohen, 1988), this pattern of selectivity indicates that ZULU continuers represent a positively selected subset of the original sample. In the highly educated sample no differences were found between continuers ($n = 39$, 45.9%) and dropouts ($n = 46$). All participants gave written informed consent before the testing procedure. In addition, the ZULU sample received 50 CHF (approx. 43 USD) for study participation.

Procedure and Interventions

All participants underwent a short medical history form to exclude past or current presence of neurological and psychiatric illnesses, and substance abuse. Furthermore, the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was utilized as screening if participants were suspected of cognitive impairment. Of the total score of 30, threshold values for the highly educated sample were 26 points and 24 points for the normal educated individuals, respectively. If eligibility criteria were met, participants were tested individually at the Department of Psychology in Zurich for 75 minutes with an extensive cognitive test battery. Since some of the cognitive tests differed between the two studies, not all of them were included in the statistical analysis. Due to health issues, two individuals of the highly educated sample had to be tested at their homes.

Cognitive Assessment

All participants were administered a cognitive test battery measuring episodic memory (story recall, paired associates), working memory and perceptual speed. All tests, except for story recall, were computerized. In the following section, the cognitive tasks are described

briefly (see Zimprich et al., 2008, for a more detailed description and test-retest reliabilities of the cognitive tasks).

Episodic Memory

To assess the ability to recall meaningful memory units, ‘Story A’ of the logical memory subtest of the German version of the ‘Wechsler Memory Scale-Revised’ (WMS-R; Härting et al., 2000) was read aloud by the experimenter. Immediately afterwards, participants were asked to recall as many of the 25 semantically meaningful units of the story as possible. The dependent variable was the number of words correctly recalled (range 0-25).

To measure the ability to recall associative couplings, the subtest ‘Visual Paired-Associates’ of the German version of the ‘Wechsler Memory Scale-Revised (WMS-R)’ was combined with the ‘Munich Verbal Test’ (MVGT; Ilmberger, 1988). During the learning trial, twelve semantically unrelated word pairs were presented on the computer screen for 4 s each. Participants were asked to read them aloud, before the next word pair was presented after an interval of 1 s. For retrieval, only the first word of the word-pair was shown, followed by a question mark (e.g., salad – ?). Moreover, cue words were presented in a different order than during encoding. Participants had to recall out loud the associated target word. Two test trials were conducted consecutively with a different order of word-pairs. The dependent variable was the number of words correctly recalled (range 0-12).

Working Memory

Working memory was assessed with reading span task where sentences consisting of seven to nine words were presented on a computer screen (Schumacher & Martin, 2009). The statements were either meaningful or not. Participants had to read the sentences out loud and decide whether they described a situation which averagely could occur. On the computer keyboard, they indicated ‘J’ (for ‘ja’ = yes), and ‘N’ (for ‘nein’ = no). Subsequently, the next sentence was presented on the screen. Further, participants had to memorize the last word of each sentence. After several sentences, three question marks appeared on the screen,

demanding the recall of the last words of the previously shown sentences in the same order in which they had been presented (Schumacher & Martin, 2009). The dependent variable was the percentage of words recalled in correct order (range 0-1).

Perceptual Speed

To assess perceptual speed, an adapted version of the ‘Letter Digit Substitution Test’ from WMS-R (Härting et al., 2000) was utilized. Key items were numbers from one to five, each paired with a different letter. The number-letter pairs were presented in a table above the test items. Below the table, a cue letter was presented with a question mark. Participants had to press the corresponding number on the keyboard. Each trial comprised a new code table and cue letter. Participants had 90 s to work on the task. Scores comprised the number of correctly solved items, ranging between zero and 75.

Self-report Measures

Before participants accomplished the cognitive test battery, they filled out two questionnaires. One questionnaire consisted of sociodemographic variables and questions regarding the objective and subjective health (see Zimprich et al., 2008), and the other one consisted of questions concerning cognitive engagement.

Subjective Health

Participants had to fill in questions about their medical history. Furthermore, they were asked five questions concerning their subjective health, like for example “If you compare yourself with other people of your own age. How healthy do you feel?”. They had to indicate their answers on a 3-point to 6-point Likert-scale (depending on the question).

Cognitive Engagement

In the adapted version of the ‘Typical Intellectual Engagement (TIE) Questionnaire’ (Dellenbach & Zimprich, 2008), all participants reported their engagement in cognitively demanding activities. The 17 items had to be judged on a 5-point Likert-scale ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scoring implies an individual’s enjoyment of

intellectually challenging activities. In the highly educated sample, Cronbach's alpha was .74 (T1) and .73 (T2). In the averagely educated sample, Cronbach's alpha was .84 (T1) and .83 (T2). The internal consistencies of all measures in both groups at each time point ranged from acceptable to good.

Statistical Analysis

In a first step, mixed (between- and within-subjects) analyses of variances (ANOVAs) were conducted to investigate if there is an interaction between education groups (between-subjects) and time (within-subjects) on different cognitive task performances (dependent variables). Contrasts were set to the sum-to-zero convention for effect weights.

We are aware that the sample sizes of our two groups differ (i.e., 236 averagely educated individuals and 39 highly educated individuals). Thus, we addressed this issue by calculating mixed ANOVAs with robust estimators. In general, it should be noted that this study is not an experimental study, but rather a field study in which the distribution of included averagely and highly educated individuals reflects the distribution of averagely and highly educated individuals in the population. To illustrate, Switzerland's population constituted of 8'419'600 individuals in 2016, thereof were 3669 professors, that is 0.05% of the population (Federal Institution Statistics Switzerland, 2016). Mixed ANOVAs on trimmed means (Wilcox, 2012) were calculated to check whether the results are robust. The interpretation of results is based on robust ANOVAs only. This type of analysis is resistant to deviations from the assumptions of the traditional ordinary-least-squares ANOVA as well as robust to outliers. Thus, the standard error of the trimmed mean is less affected by deviations from normality and sphericity (i.e., unequal between-subjects group sizes) than the normal mean, because extreme observations (i.e., in the tail of a distribution) are censored or removed (Keselman, Algina, Wilcox, & Kowa, 2000). The amount of trimming was set to 0.2 (Keselman et al., 2000). When referring to standardized mean differences (within groups, Table 1) in the results section, the single-group pretest-posttest effect size was used (Morris &

DeShon, 2002). Mixed ANOVAs were calculated using RStudio Version 0.99.442 (RStudio Team, 2015) with the R function *aov* of the package *stats* (R Core Team, 2015) for the traditional ANOVAs. The R function *bwtrim* of the package *WRS2* (Mair, Schoenbrodt, & Wilcox, 2017) was used for the trimmed mean ANOVAs.

4.1.3 Results

The mean values and standard deviations of the socio-demographic variables, subjective health, TIE, and cognitive test scores of the highly and averagely educated samples at both measurement occasions are displayed in Table 1. Additionally, it is shown whether individuals retained the same rank ordering on the variables of interest over time (rank-order stability). We found relatively high rank-order stabilities for all variables. In other words, individuals generally retained their relative positions on the variables of interest over time. But although rank-order stability was relatively high, this does not imply that there were no reliable individual differences in change of subjective health, TIE, and cognitive performance.

Next, we tested for differences between the two groups concerning the socio-demographic variables *age*, *education*, and *income*. On average, the highly educated sample was slightly older ($M_{T1} = 72.87$, $SD_{T1} = 5.43$) than the averagely educated sample ($M_{T1} = 72.67$, $SD_{T1} = 4.43$). This difference, 0.20, 95% CI [-1.242, 1.654], was not significant, $t(281) = .280$, $p = .780$, representing a very small effect size ($d = 0.05$). With regard to years of education, the groups significantly differed in their means as shown in Table 1. This difference, 7.67, 95% CI [6.710, 8.627], $t(280) = 15.75$, $p < .001$, represented as expected a large effect size ($d = 2.50$). Furthermore, the highly educated sample reported a higher income ($M_{T1} = 6.98$, $SD_{T1} = 0.15$) than the averagely educated sample ($M_{T1} = 4.61$, $SD_{T1} = 1.50$). This difference, 2.37, 95% CI [2.165, 2.566], was significant, $t(242) = 23.19$, $p < .001$, and represented a large effect size too ($d = 1.58$).

Moreover, we tested for differences between the two groups and time concerning *subjective health* and *TIE*. There was no significant main effect of education group on health,

$F(1, 274) = 0.20, p = .653$. Nevertheless, there was a significant main effect of time on health, $F(1, 274) = 17.02, p < .001$. The effect size (eta-squared) was small ($\eta^2 = 0.01$). The interaction between education group and time was not significant, $F(1, 274) = 0.08, p = .777$. However, there was a significant main effect of education group, $F(1, 271) = 23.62, p < .001$, on TIE, indicating that TIE was different between highly and averagely educated individuals. The effect size was small ($\eta^2 = 0.07$). The main effect of time on TIE was not significant, $F(1, 254) = 2.61, p = .107$. The interaction effect between education group and time was neither, $F(1, 254) = 3.86, p = .051$.

Table 1. *Descriptive Statistics*

Variables	High education sample ($N = 39$)						Average education sample ($N = 236$)					
	T1		T2		T1 --> T2	Rank-order	T1		T2		T1 --> T2	Rank-order
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>SMD</i>	<i>r</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>SMD</i>	<i>r</i>
Age	72.87	5.43	78.62	5.46	1.06		72.67	4.43	77.90	4.42	1.18	
Education (years)	20.78	2.76					13.11	3.07				
Income	6.98	0.15	6.87	0.62	-0.75		4.61	1.50	4.51	1.45	-0.07	
Health (sum)	17.93	1.87	17.54	2.71	-0.21	.53***	18.29	1.84	17.74	2.24	-0.30	.50***
TIE (sum)	66.20	6.40	63.67	6.81	-0.40	.45**	57.99	9.67	58.06	8.99	0.01	.78***
Cognitive Tasks												
Letter Digit	33.75	5.46	32.46	7.39	-0.24	.69***	32.69	6.43	28.71	6.71	-0.62	.77***
Paired Associates	3.90	2.59	4.00	2.86	0.04	.68***	3.32	2.45	3.56	3.05	0.10	.55***
Reading Span	0.77	0.15	0.74	0.13	-0.21	.50**	0.61	0.17	0.62	0.24	0.06	.49***
Story Recall	14.88	3.21	14.00	3.55	-0.27	.44**	14.90	3.75	13.51	3.82	-0.37	.51***

Note. TIE = cognitive engagement; *M* = mean; *SD* = standard deviance; *SMD* = standardized mean differences; *r* = rank-order stability.

Education was measured at T1 only. Income is coded as followed 1 < 2,000 CHF, 2 = 2,000 CHF – 3,000 CHF, 3 = 3,000 CHF – 4,000

CHF, 4 = 4,000 CHF – 6,000 CHF, 5 = 6,000 CHF – 8,000 CHF, 6 = 8,000 CHF – 10,000CHF, 7 > 10,000CHF.

** $p < .01$, *** $p < .001$.

Mixed ANOVAs

There were significant main effects of education group, $F(1, 268) = 7.42, p = .007, \eta^2 = 0.02$ (small effect size), and time, $F(1, 266) = 174.80, p < .001, \eta^2 = 0.07$ (small effect size), on the letter digit substitution task. Furthermore, there was a significant interaction effect between education group and time, $F(1, 266) = 12.43, p < .001, \eta^2 = 0.004$ (very small effect size), indicating that performance of the letter digit substitution task across time was different between highly and averagely educated individuals.

No significant main effects were found of education group, $F(1, 269) = 2.48, p = .116$, and time, $F(1, 269) = 1.93, p = .166$, on the paired associates task. Likewise, there was no significant interaction effect between education group and time, $F(1, 269) = 0.07, p = .796$.

For the reading span task, a significant main effect of education group was found, $F(1, 268) = 24.88, p = .000, \eta^2 = 0.06$ (small effect size). However, there was no significant main effect of time on the reading span task, $F(1, 266) = 0.01, p = .920$, as well as no significant interaction effect, $F(1, 266) = 1.36, p = .245$.

Lastly, there was no significant main effect of education group on the story recall task, $F(1, 268) = 0.28, p = .595$. Nevertheless, there was a significant main effect of time on the story recall task, $F(1, 265) = 31.43, p < .001, \eta^2 = 0.03$ (small effect size), whereas the interaction between education group and time was not significant, $F(1, 265) = 1.20, p = .274$.

Mixed ANOVAs using Robust Estimators

Analyzing the data with the function *bwtrim*, the main effect of education group on the letter digit substitution task was still found with the test statistics being $F = 6.74, p = .013$. However, there was no main effect of time on the letter digit substitution task, $F = 3.34, p = .073$. The interaction effect between education group and time was no longer significant using robust estimators ($F = 2.11, p = .153$), indicating that performance of the letter digit substitution task across time was the same for highly and averagely educated individuals.

The main effect of education group on the paired associates task was, consistent with traditional ANOVA results, not significant ($F = 2.34, p = .133$), neither was the main effect of time ($F = 0.01, p = .904$) nor the interaction ($F = 0.08, p = .784$).

In line with the results from the traditional ANOVA, there was a significant main effect of education group, $F = 14.05, p < .001$, and a non-significant main effect of time, $F = 0.20, p = .662$, on the reading span task. The interaction effect was neither significant, $F = 0.89, p = .351$.

For the story recall task, there was no significant main effect of education group ($F = 0.08, p = 0.781$), as already found with the traditional ANOVA. In contrast to the traditional ANOVA, the time effect on the story recall task was no longer significant when computed with trimmed means ($F = 1.92, p = .169$). The interaction between education group and time was not significant ($F = 0.77, p = 0.384$).

In summary, the only effects which remain significant using trimmed means are the main effects of education group on the letter digit substitution and reading span task. Highly educated individuals performed significantly better on the letter digit substitution task at the second measurement occasion than averagely educated individuals ($d = .55$). Moreover, highly educated individuals showed better reading span performance than averagely educated individuals at T1 ($d = .96$) as well as at T2 ($d = .53$). These differences reflect moderate to strong effects (Cohen, 1988).

Additional analyses

As reported in our descriptive results' section, TIE was different across education group. Therefore, we decided to include TIE as a covariate in two additional analyses. To be more specific, we calculated robust analyses of covariances (ANCOVAs, see Field, Miles, & Field, 2012) for the letter digit substitution and reading span task, because these were the only two effects which remained significant using trimmed means' ANOVAs. The results are shown in Table 2.

Table 2. *Results of the Additional Analyses*

Model	Diff	SE	95% CI	<i>p</i>
TIE design points at T1				
Letter digit substitution				
63	-2.57	1.29	[-6.110, 0.976]	0.062
64	-1.96	1.43	[-5.949, 2.032]	0.190
65	-1.68	1.33	[-5.351, 1.986]	0.222
66	-1.50	1.24	[-4.859, 1.850]	0.238
Reading span				
60	-0.23	0.03	[-0.314, -0.150]	0.000
63	-0.25	0.03	[-0.339, -0.163]	0.000
64	-0.23	0.04	[-0.337, -0.122]	0.000
67	-0.16	0.04	[-0.283, -0.042]	0.001
69	-0.16	0.04	[-0.2703, -0.053]	0.000
TIE design points at T2				
Letter digit substitution				
63	-4.37	2.44	[-11.366, 2.629]	0.097
64	-3.03	2.28	[-9.488, 3.422]	0.205
65	-3.38	2.14	[-9.400, 2.645]	0.136
66	-3.59	2.27	[-10.240, 3.068]	0.143
Reading span				
60	-0.12	0.03	[-0.208, -0.024]	0.002
63	-0.14	0.04	[-0.232, -0.042]	0.000
64	-0.13	0.04	[-0.229, -0.040]	0.000
67	-0.13	0.04	[-0.257, -0.011]	0.006
69	-0.13	0.05	[-0.276, -0.014]	0.019

Note. TIE = Typical cognitive engagement (covariate). The design points refer to points in TIE where the slopes are the same in both groups. Diff = difference between the two samples. *SE* = standard error. CI = confidence interval. *p* = *p*-value. CI are adjusted to control the probability of at least one Type I error, the *p*-values are not.

By taking into account the multiple testing nature of the problem, we found significant group differences for the reading span task at both measurement occasions where the trimmed means differ at all five design points. In other words, in all cases the highly and averagely educated samples differed significantly in their mean level of the reading span task at both measurement occasions adjusted for TIE. If there were no significant differences for values of TIE around a specific design point, this would suggest that averagely educated individuals who reported levels of TIE around this specific design point did not perform worse compared to highly educated individuals. For the letter digit substitution task, we found no significant group differences at both measurement occasions, indicating that averagely educated individuals who reported levels of TIE around 63-66 did not perform worse compared to highly educated individuals on the letter digit substitution task.

4.1.4 Discussion

The goal of this study was to investigate the role of education on cognitive development in older age over a period of five years, considering factors such as income, subjective health and cognitive engagement. Against our assumptions that in the highly educated sample, education might protect against cognitive decline and help to stabilize cognitive performance over time, there seems to be no direct effect of education on cognitive development in older age over a period of five years. Although the performance of the highly educated sample outranked the one of the normal educated sample in tests of working memory and perceptual speed, the performance of both groups was fairly stable irrespective of how much they earned or how healthy they felt. The same stability in performance could be found in tests of episodic memory. These findings are in line with other longitudinal studies on cognitive aging. Christensen et al. (1997) even found that blue-collar workers improved from the first to the second measurement point in a test reflecting crystallized abilities, whereas the academics decreased. Even though Zahdone et al. (2015) stated that the performances of their older participants decreased in tests of verbal fluency, verbal episodic

memory, and working memory over a period of twelve years, they did not find any moderating effect of education on cognitive decline with aging. This leads to the assumption that although education can act as a stimulator of cognitive performance, it does not seem to influence cognitive development in older age. Moreover, our additional analyses suggest that it might not even be education but rather cognitive engagement which stimulates cognitive performance in older age, at least in some cognitive domains. To be more specific, the current study found that averagely educated individuals who reported higher levels of TIE (i.e., around 63-66) did not show lower perceptual speed than highly educated individuals. As such, cognitive engagement may be a protective or stimulating factor regarding perceptual speed. This is in line with previous research suggesting that cognitive engagement contributes to cognitive reserve, thus restricting cognitive decline (Hertzog, Kramer, Wilson, & Lindenberger, 2008; Tucker & Stern, 2011; Wilson et al., 2002; Wilson, Segawa, Boyle, & Bennett, 2012). That cognitive engagement functions as a stimulator of cognitive performance supports the “use it or lose it” hypothesis. Hultsch, Hertzog, Small, and Dixon (1999) stated that maintaining cognitive engagement through participation in everyday cognitive activities seems to buffer older adults against cognitive decline. However, they correctly noticed that older adults with higher cognitive abilities averagely lead more active lives compared to normal-ability older adults until cognitive decline limits their activities. Therefore, it might as well be the case that cognition influences cognitive engagement and not the other way around. Since the highly educated sample in our study demonstrated a slight decrease in cognitive engagement but not in cognitive functioning, this would rather support the hypothesis of Hultsch et al. (1999) of cognitive engagement as a buffer. However, one could also argue that a decrease in cognitive functioning might manifest itself first in everyday cognitive behavior before it is measurable in an experimental test setting.

Although this study has several strengths, including the unique sample of highly educated individuals, the longitudinal design, and the wide range of assessed cognitive

abilities, it has also certain limitations that we would like to discuss in the following. First, it must be cautioned some evidence for selective attrition in the averagely educated sample. In contrast to the highly educated continuer sample the averagely educated continuer sample differed in some variables compared to the averagely educated dropouts, even though the differences were in the small effect size range. However, it should be noted that attrition is a well-known problem in aging research (McArdle, Hamagami, Elias, & Robbins, 1991). Second, the averagely educated sample was tested three times, whereas the highly educated sample was tested two times within a 5-year time interval. For this study, we focused on only two measurement occasions of the averagely educated sample to compare their cognitive development to a highly educated sample. Because the same cognitive tasks were administered at all measurement occasions, one could argue that the conditions between the two samples were different. However, the practice effects of the averagely educated sample might be negligible since the averagely educated individuals did not outperform the highly educated individuals. Furthermore, it must be mentioned that the highly educated sample not only differed concerning their education but also concerning gender. Since professorship was and still is to a certain extent a man-dominated profession at the University of Zurich, the percentage of women in the highly educated sample is negligible.

To sum up, the findings indicate that most cognitive abilities of healthy older adults tend to stay stable over a period of five years independent of educational background, subjective health or income of the tested individuals. Interestingly, cognitive engagement seems to have the higher impact on cognition than education has. However, the causal direction of changes in cognitive engagement and cognitive function is still unclear. The question also remains unanswered as to why cross-sectional studies find beneficial effects of education on cognitive aging, whereas longitudinal studies do not. To answer these unresolved issues, it is essential to follow individuals such as described in this study for as long as possible to not only detect short term relationships but also long term causal

directions. Coming back to our question stated in the title “Are professors special?”. It seems that professors are special in the way that they certainly can be described as cognitively high performers and in the extent to which they choose and enjoy a variety of cognitive demanding activities. However, concerning their cognitive development in older age there is evidence missing which would indicate that their cognitive development in older age might be special as well.

4.2 Study 2: Long-Term Associations between Cognitive Abilities and Personality

Traits⁵

4.2.1 Introduction

Older age is characterized by individual changes in various life domains such as health, cognition, and social environment. As people age, they become more susceptible to individual and environmental changes and non-normative events (Baltes, Lindenberger, & Staudinger, 2006). For example, research suggests that cognitive decline is a natural part of aging. Diverse cognitive abilities tend to decline in older age, mainly those considered to represent fluid abilities such as reasoning (Singh-Manoux et al., 2012) and processing speed (Salthouse, 1996). Nevertheless, individuals differ with respect to their cognitive performance (Matthews, 2009) and show substantial interindividual variability in cognitive decline (Wilson et al., 2002). This issue leads to the question why individuals maintain, improve or deteriorate their cognitive abilities. A considerable amount of studies identified different factors which could explain individual differences in change in cognitive abilities in older age (see Daffner, 2010, for a review). Among these studies, there has been an increased interest in examining the role of personality traits in cognitive aging.

Cognitive abilities and personality traits are core domains of individual functioning. Neither cognitive abilities nor personality traits develop solely as a function of brain development; both also rely on experience (Hofer & Alwin, 2008; Roberts & Mroczek, 2008). Both domains are moderately heritable and develop across the lifespan, but compared to cognitive abilities, developmental, social, and institutional pressures on personality unfold more slowly over the lifespan (Briley & Tucker-Drob, 2017). Furthermore, they show different normative developmental trajectories over time. That is, cognitive abilities tend to

⁵A similar version of this study has been published in *Journal of Research in Personality* (Copyright notice: Elsevier). This chapter may not exactly replicate the final version published in the Elsevier journal. It is not the copy of record. Original article published by Elsevier (*Journal of Research in Personality*): Aschwanden, D., Martin, M., & Allemand, M. (2017). Cognitive abilities and personality traits in old age across four years: More stability than change. *Journal of Research in Personality*, 70, 202–213.

increase throughout early adulthood and then begin to show declines (cf. Craik & Bialystok, 2006). In older age, certain cognitive abilities show at least a small decline with advanced age in many, but not all, healthy individuals. Furthermore, these changes can be subtle and do not need to translate into impairment of daily activities (Howieson, 2015). Regarding personality traits, most mean-level change occurs between the ages of 20 and 40 years (cf. Roberts, Walton, & Viechtbauer, 2006). However, personality traits continue to change even in older age (e.g., Allemand, Zimprich, & Martin, 2008; Kandler, Kornadt, Hagemeyer, & Neyer, 2015; Wortman, Lucas, & Donnellan, 2012), thus tending to slightly decrease in late life (e.g., Lucas & Donnellan, 2011), except for neuroticism which again tends to increase (e.g., Kandler et al., 2015).

Although there is some empirical evidence for smaller, albeit inconsistent cross-sectional associations between the two domains of individual functioning (e.g., Baker & Bichsel, 2006; Soubelet & Salthouse, 2011), less is known about the longitudinal associations between cognitive abilities and personality traits in older age (e.g., Curtis, Windsor, & Soubelet, 2015). This study thus examined stability and change of six cognitive abilities (memory, processing speed, reasoning, verbal knowledge, verbal learning, and working memory) and three personality traits (openness, neuroticism, and conscientiousness) as well as their longitudinal associations across four years in older age.

Understanding the longitudinal associations between cognitive abilities and personality traits in older age is important for the following reasons. First, it is of interest whether stabilities and changes in one domain are related to the other domain, because both domains are central concepts defining daily functioning in older age. Personality traits describe individual differences in typical cognitive and affective experiences and behaviors. Therefore, specific traits such as openness may help older adults to maintain their cognitive abilities as they age (Baker & Bichsel, 2006), but they may also serve as a source of vulnerability with regard to cognitive decline and cognitive impairment (Chapman et al.,

2012; Terracciano, Stephan, Luchetti, Albanese, & Sutin, 2017). It is also reasonable to assume that cognitive abilities are a requisite condition for personality traits to remain stable or to change in older age (cf. Moutafi, Furnham, & Crump, 2003). Second, knowing which personality traits or cognitive abilities have maintenance functions for the respective domains may help to strengthen these particular personality traits and cognitive abilities, respectively. For instance, Graham and Lacham (2012) found that stability in neuroticism and openness (compared to change in either direction) was related to better reasoning performance and faster reaction time. This indicates that maintaining a stable personality may be more beneficial than even socially desirable change (such as decline in neuroticism) for some variables (except for neuroticism and reaction time, for which decreases were also adaptive). Third, shedding light on the associations between cognitive abilities and personality traits can provide guidance for researchers to develop specific interventions such as personality interventions depending on cognitive characteristics or cognitive interventions for different personality types (Graham & Lachman, 2014).

Cognitive Abilities and Personality Traits

Previous research examined cross-sectional associations between cognitive abilities and personality traits but the findings are mixed (Ashton, Lee, Vernon, & Jang, 2000; Gignac, Stough, & Loukomitis, 2004; Zimprich, Allemand, & Dellenbach, 2009). Some of the inconsistency can be attributed to differences in measures of cognitive abilities and personality traits, different age groups with respect to older age, and the inclusion of different covariates, mediators and moderators across studies (cf. Luchetti, Terracciano, Stephan, & Sutin, 2016).

The most consistent personality-cognition associations were found for openness and neuroticism, whereas openness is positively related to measures of cognitive abilities, and neuroticism is negatively associated with measures of cognitive abilities (e.g., Graham & Lachman, 2012; Schaie, Willis, & Caskie, 2004). Correlation coefficients for the associations

between openness and cognitive abilities ranged between .18 and .70 depending on the ability one considered (Graham & Lacham, 2014; Schaie et al., 2004; Soubelet & Salthouse, 2011; Zimprich et al., 2009). Correlation coefficients for associations between neuroticism and cognitive abilities ranged between $-.16$ and $-.50$ (cf. Curtis et al., 2015; Gow, Whiteman, Pattie, & Deary, 2005). Correlation coefficients for the associations between conscientiousness and cognitive abilities were around $-.20$ to $.16$ (Booth, Schinka, Brown, Mortimer, & Borenstein, 2006; Soubelet, 2011), alluding to inconsistent associations.

Indeed, the correlation coefficients reported in literature indicate a wide range, but on average, the associations between cognitive abilities and personality traits seem to be rather weak. A possible explanation for these weak associations may be that cognitive abilities and personality traits are assessed on different scales. That is, individuals show what they are able to perform (maximal performance) while solving cognitive tasks, and they describe their behaviors and attitudes (typical behaviors) while completing a personality questionnaire. Early work already pointed out that cognitive tests measure maximal performance in contrast to personality questionnaires which provide measures of typical performance (e.g., Ackerman, 1994; Ackerman & Heggestad, 1997).

Although recent studies reported significant, albeit weak cognition-personality associations, less is known about these associations with respect to older age, and the few existing findings show mixed results. One reason is that most previous work had cross-sectional study designs. Another reason is that the sparse longitudinal studies on the cognition-personality associations focused on unidirectional effects (i.e., personality traits only at one measurement occasion as predictors of cognitive abilities). Finally, previous work typically focused on a limited range of cognitive abilities. This study thus sought to address these limitations.

Cognitive Abilities and Openness

Individuals high in openness generally tend to be curious, creative, sensitive to aesthetics, as well as open to new ideas and experiences (Costa & McCrae, 1992a). Hence, there are at least three arguments for a positive association between openness and cognitive abilities. First, openness may influence the engagement in cognitive activities, thus supporting the maintenance of cognitive functioning or even increase the levels of cognitive abilities. Second, as openness is characterized by flexible and open-minded thinking, individuals may solve problems more creatively. Third, higher levels in cognitive abilities may promote the interest in cognitive activities which results in higher openness scores. The majority of studies have reported that higher openness is linked to better cognitive performance, although the effects are generally small (cf. Curtis et al., 2015). As such, it is likely that open individuals are more prone to engage in cognitively stimulating activities such as reading newspapers, solving cross-word puzzles, or using the computer. In turn, these activities may positively affect cognitive abilities, contribute to cognitive reserve, and help to maintain cognitive functioning in older age (Chapman et al., 2012; Gow et al., 2005; Sharp, Reynolds, Pedersen, & Gatz, 2010). It may also be that cognitive abilities influence the development and maintenance of openness. For example, individuals with lower cognitive abilities may have more difficulties to cope with novel situations or challenging experiences, thus they are less open to new experiences than individuals with higher cognitive abilities (Moutafi et al., 2003).

Cognitive Abilities and Neuroticism

Individuals high in neuroticism tend to experience negative emotions such as anger, anxiety, and depression, and to be emotionally unstable (Costa & McCrae, 1992a). Therefore, it is reasonable to expect negative associations between neuroticism and cognitive abilities in older age, because negative emotions may impair cognitive performance. Most studies have reported that higher neuroticism is linked to poorer cognitive performance (see Curtis et al., 2015, for a review), but several studies did not find significant cross-sectional associations

between neuroticism and measures of cognitive abilities (e.g., Jelicic et al., 2003). One hypothesis is that neurotic individuals are more anxious and prone to intrusive thinking as well as to distraction that could impair their ability to focus on cognitive performance tasks, which then results in poorer cognitive functioning (Gold & Arbuckle, 1990; Graham & Lachman, 2012; Moutafi, Furnham, Paltiel, 2004). However, an alternative hypothesis would suggest that decline in cognitive ability causes older adults to become more anxious, so increasing anxiety leads to higher neuroticism scores on self-report scales (Curtis et al., 2015).

Cognitive Abilities and Conscientiousness

Individuals high in conscientiousness tend to be organized, goal-directed, persistent, self-controlled, and self-disciplined (Costa & McCrae, 1992a). It is thus reasonable to expect positive associations between conscientiousness and cognitive abilities, because conscientiousness may help to maintain previous levels of cognitive abilities as individuals age. However, previous studies found mixed results for the associations between cognitive abilities and conscientiousness (see Curtis et al., 2015, for a review). Three hypotheses are currently discussed. First, conscientiousness is positively related to cognitive abilities, because it influences health behaviors, which, in turn, are protective against age-related changes in brain (Sutin et al., 2011). Second, it might be that better cognitive abilities allow individuals to maintain their levels of conscientiousness with increasing age (Möttus, Johnson, Starr, & Deary, 2012b). Third, conscientiousness is negatively linked to cognitive abilities, whereby individuals with lower cognitive abilities become more hardworking and organized over time in order to compensate for their lower cognitive abilities (Chamorro-Premuzic & Furnham, 2004; Moutafi et al., 2004; Rammstedt, Danner, & Martin, 2016).

Goals of the Present Study

The present study investigated stability and change of six different cognitive abilities and three different personality traits, and their longitudinal associations across four years in older age. We had two main goals. The first goal was to examine stability and change of

cognitive abilities and personality traits separately across four years. Although four years is a relatively short time period, results show that significant individual differences exist with respect to the rates and direction of changes in older adults (aged between 61 to 100 years) across relatively short time intervals between one to six years (Ghisletta & Lindenberger, 2003; Lindenberger & Reischies, 1999). In particular, we investigated whether individuals retain the same rank ordering on the variables of interest over time (rank-order stability) and whether the group of individuals increases or decreases on variables of interest over time (mean-level change). So far, very few studies investigated rank-order stability and mean-level change of cognitive abilities and personality traits in older age. Based on the sparse existing research (Hertzog, Dixon, Hultsch, & MacDonald, 2003; Kandler et al., 2015; Möttus et al., 2012a; Wortman et al., 2012), we expected medium-sized to high rank-order stabilities and small mean-level changes for both cognitive abilities and personality traits across four years.

The second goal was to investigate the longitudinal associations between cognitive abilities and personality traits in terms of cross-lagged effects. Cross-lagged models allow to examine whether levels in one domain such as cognitive abilities are predicted by previous levels of the other domain such as personality traits (e.g., Grimm, An, McArdle, Zonderman, & Resnick, 2012). As such, we were interested in the basic (that is, levels) bidirectional longitudinal relationship between cognitive abilities and personality traits. To date, only few studies have tested whether cognitive abilities influence personality traits (e.g., Curtis et al. 2015). Furthermore, this is one of the first studies testing cross-lagged effects between cognitive abilities and personality traits. We focused on six different cognitive abilities rather than on a general cognitive ability score, tapping the full potential of our extensive cognitive assessment. The underlying idea of this modeling strategy is that levels in one cognitive domain may be related to levels of personality traits, whereas others may not (and vice versa). Given the paucity of evidence on longitudinal studies, we did not make specific predictions for the different cognitive abilities. We expected bidirectional associations between the two

domains. With regard to cross-sectional literature, we expected openness and conscientiousness to be positively related to the measures of cognitive abilities, whereas neuroticism was expected to be negatively associated with cognitive abilities. In general, we expected weak associations between cognitive abilities and personality traits because they represent different domains of individual functioning, and they are also assessed on different scales using different methods. That is, cognitive tasks measure maximal performance, whereas self-report personality questionnaires measure typical behaviors.

4.2.2 Methods

Participants

Participants come from the Zurich Longitudinal Study on Cognitive Aging (Zürcher Längsschnittuntersuchung zum kognitiven Altern, ZULU; see Zimprich et al., 2008). ZULU is an ongoing longitudinal study on the structure and development of cognitive abilities in older age. It started in 2005, followed by reassessments in 2006 and 2010. Participants were recruited through three different channels. That is, (1) the registry of the city of Zurich, (2) the University of Zurich lecture series for senior citizens, and (3) by advertisements in two local newspapers, flyers or word of mouth by other participants. The ZULU sample was designed to be representative of older adults living in Switzerland (for more information, see Dellenbach & Zimprich, 2008; Mascherek & Zimprich, 2012; Zimprich et al., 2008). Because the focus of ZULU is on cognition, only three personality traits (i.e., openness, neuroticism, conscientiousness) were part of the assessment protocol to present as little burden to the participants as possible. Given that the three self-report measures of personality traits were included at the second and third measurement occasion only, this study focused on these two time points. As from now, it is referred to the two measurement occasions as T1 (2006) and T2 (2010). At T1, the sample consisted of 335 older adults.

To test for attrition effects, dropouts ($n = 99$) who only participated at T1 (or from whom no data on the variables of interest at T2 exist) were compared with continuers ($n =$

236) who participated at both measurement occasions (T1 and T2). Continuers were slightly younger ($d = -.23$), healthier ($d = .35$), more open ($d = .22$), more conscientious ($d = .26$), less neurotic ($d = -.45$), and slightly higher educated ($d = .26$) than dropouts. The groups did not significantly differ regarding their cognitive performance in verbal knowledge ($d = -.03$) and reading span ($d = .19$). Nevertheless, continuers showed slightly better performance in the cognitive tasks number comparison ($d = .36$), identical pictures ($d = .48$), letter digit substitution ($d = .49$), standard progressive matrices ($d = .26$), five verbal learning trials (d 's = between .28 and .48), paired associates ($d = .49$), story recall ($d = .29$), and picture recall ($d = .31$). Although these differences reflect small effects ($d < .50$; Cohen, 1992), this pattern of selectivity indicates that continuers represent a positively selected subset of the original sample. The findings in this article are based explicitly on the continuer sample (53.8% male). There were no signs of cognitive impairment as assessed by the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). The mean age was 74.12 years ($SD = 4.40$, range = 66-81 years). Mean education was 13.11 years ($SD = 3.07$). Average subjective health was 3.61 ($SD = 0.39$) as measured on a Likert scale ranging from 1 (*very poor*) to 6 (*excellent*).

Measures of Cognitive Abilities

Data from ten cognitive tasks were used to measure six different cognitive abilities. The same cognitive tasks were administered at all measurement occasions. In the following section, the cognitive tasks are described briefly (see Zimprich et al., 2008, for a more detailed description and test-retest reliabilities of the cognitive tasks).

Memory tasks. Three tasks were used to measure memory. First, the paired associates task consisted of 12 semantically unrelated word pairs taken from the German version of the Wechsler Memory Scale-Revised (WMS-R; Härting et al., 2000) and from the Munich Verbal Memory Test (MVGT; Ilmberger, 1988). Second, the story recall task consisted of Story A of the logical memory subtest of the German version of the WMS-R (Härting et al., 2000).

Third, the picture recall task comprised 12 pictures taken from the Nuremberg Age Inventory (Oswald & Fleischmann, 1999).

Processing speed tasks. Three tasks were used to measure processing speed. First, the number comparison task comprised 60 items (Ekstrom, French, Harman, & Dermen, 1976). Second, the identical pictures task consisted of 60 items taken from the Educational Testing Service (ETS; Ekstrom et al., 1976). Third, the letter digit substitution task comprised 75 items (Jolles, Houx, Van Boxtel, & Ponds, 1995).

Reasoning task. The standard progressive matrices task consisted of 24 items (12 items from Set A and 12 items from Set B of the Standard Progressive Matrices by Raven, 1998).

Verbal knowledge task. The spot-a-word task consisted of 37 items taken from Version A of a widely used German vocabulary test (MWT; Lehrl, 1999).

Verbal learning task. Five trials of a word list recall were used to assess verbal learning. This task comprised of 27 unrelated, but meaningful two- to three-syllable words taken from a manual of German word norms (Hager & Hasselhorn, 1994). To build verbal learning scores, recall performance difference scores were calculated by subtracting the score for the first trial from the scores of the other trials. Thus, four difference score variables were created (verbal learning trial 2 minus verbal learning trial 1, verbal learning trial 3 minus verbal learning trial 1, verbal learning trial 4 minus verbal learning trial 1, and verbal learning trial 5 minus verbal learning trial 1).

Working memory task. The reading span task was a modified version of the task used by Daneman and Carpenter (1980).

Measures of Personality Traits

Openness, neuroticism, and conscientiousness were measured using the German version of the NEO-Five-Factor Inventory (NEO-FFI; Borkenau & Ostendorf, 1993). The items were rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). For openness, Cronbach's alpha was .74 (T1) and .75 (T2), whereas the omega

hierarchical estimates (Zinbarg, Revelle, Yovel, & Li, 2005) were .59 (T1) and .56 (T2). For neuroticism, Cronbach's alpha was .82 (T1) and .82 (T2), whereas the omega hierarchical estimates were .64 (T1) and .63 (T2). For conscientiousness, Cronbach's alpha was .79 (T1) and .78 (T2), whereas omega hierarchical were .64 (T1) and .55 (T2). The internal consistencies of all measures at each time point ranged from acceptable to good.

Statistical Analysis

Power analysis. The sample size of the current longitudinal data analysis was determined using the existing ZULU data. Power calculations were conducted using the “pwr” package (Champely, 2017) in R version 1.0.143 (R Core Team, 2015), and focused on the longitudinal cross-lagged correlation coefficients. However, it is difficult to refer to prior work to inform about effect size expectations, because cross-lagged designs are rare, and different methodologies were used to assess cognitive abilities (global measure vs. specific cognitive tasks). Nevertheless, the correlation coefficients' range of .11-.32 for longitudinal associations was considered as a possible scenario for the effect size based on estimates available from the literature (Chapman et al., 2012; Gow et al., 2005; Hultsch, Hertzog, Small, & Dixon, 1999; Möttus et al., 2012b). Our sample provides power of 39% to estimate a correlation coefficient of .11 at the 5% significance level, and a sample size of 645 participants would be needed to achieve 80% power for this value. If true correlation coefficients are .32, the power estimate would be 99%. Based on the given sample size, our cross-lagged longitudinal models were able to detect effects that are $>.18$ ($N = 236$, significance level = 0.05, power = 80%).

Longitudinal measurement models. Longitudinal structural equation modeling (SEM; McArdle & Nesselroade, 2014) was used to investigate the research goals. First, longitudinal measurement models were established for the six cognitive abilities and the three personality traits separately. Because reasoning, verbal knowledge, and working memory were only measured with a single cognitive test, they were estimated using manifest models (i.e., test

scores). The remaining cognitive abilities were estimated as latent constructs consisted of multiple indicators (i.e., cognitive tests or questionnaire items) at T1 and T2. For each latent personality trait, parcels were created to form three manifest indicators following the item-to-construct balance technique (Little, Cunningham, Shahar, & Widaman, 2002). Correlated residual variances were allowed for the matching parcels at T1 and T2 (Marsh & Hau, 1996).

Longitudinal measurement invariance. First, longitudinal measurement invariance (MI) of the latent measures of cognitive abilities and personality traits was established, ensuring that these constructs are comparable over time (Meredith & Horn, 2001). It seems particularly important to establish MI in older age, because older age is a phase that is particularly susceptible to individual and environmental changes and non-normative events (Baltes et al., 2006). It may be that older individuals tend to change their internal standards of perceptions due to the accompanying changes that aging brings with it. Insufficient consideration of MI may impair the interpretation of the study results (e.g., Möttus, Johnson, & Deary, 2012a). Following the recommendation by Little (2013), strong MI⁶ was established. Confirmatory factor models were fitted with increasingly restrictions on the following parameter over time: factor loadings, intercepts, and residual variances (Meredith & Horn, 2001). First, an unconstrained measurement model of configural invariance (M1) was tested. The M1 model specifies the relationship between manifest indicators and the latent constructs. Second, a model of weak MI (M2) was tested. Hence, factor loadings were set equally over time, whereas factor variances were freely estimated at T2. Third, a model of strong MI (M3) was tested. In addition to M2, indicator intercepts were set equally over time. The factor means were freely estimated over time.

Cross-lagged models. To examine the longitudinal associations between cognitive abilities and personality traits, we ran 18 bivariate autoregressive and cross-lagged regression models separately for each pair of cognitive ability and personality trait (cf. McArdle, 2009).

⁶Strict MI was not tested as our goal was to establish strong MI that allows for meaningful comparisons of means, covariances, and variances over time (cf. Little, 2013).

These models allow for the simultaneous examination of the reciprocal associations between two variables (i.e., cognitive abilities and personality traits). Overall, cross-lagged models allow estimations of initial correlations, change correlations (or more precisely, correlations between residuals), the cross-lagged paths relating to cognitive abilities' levels by previous levels of personality traits, and cross-lagged paths relating to personality traits' levels by previous levels of cognitive abilities. All cognitive and personality scores were converted into z scores (e.g., Schaie et al., 2004; Soubelet & Salthouse, 2010, 2011) to facilitate the comparison between different cognitive data types and personality scales.

In the models examining rank-order stability, mean-level change and cross-lagged effects, we controlled for potential effects of education and age (see Curtis et al., 2015, for a review of control factors considered in the field). All SEM models were estimated using the maximum likelihood estimator. We fitted all models using Mplus 7 (Muthén & Muthén, 1998-2015). To evaluate goodness of fit of the models, the chi-square (χ^2), comparative fit index (CFI), and root mean square error of approximation (RMSEA) as well as its 90% confidence intervals (CI) were examined. CFI values above .97 and RMSEA values below .06 are considered to reflect a good fit, whereas CFI values above .95 and RMSEA values below .08 are acceptable (Browne & Cudeck, 1993; Hu & Bentler, 1998). Nested chi-square ($\Delta\chi^2$) tests were used to perform model comparisons. In addition to p -values, we also provide 95% CIs when reporting the cross-lagged effects. CIs contain information about the size of an effect and its precision, thus being more informative than p -values alone (Cohen, 1994). The data, input and output files of the present study are available upon request.

4.2.3 Results

Longitudinal Measurement Invariance

Correlations and descriptive statistics for the variables of interest are displayed in Table 3. To establish MI of the measurement models, the least restrictive model (M1: Configural invariance) was fitted for each model separately. As shown in Table 4, these

models achieved acceptable fits as judged by the CFI and RMSEA. Second, factor loadings were constrained to be equal over time (M2: Weak invariance). These more restrictive models achieved acceptable fits too. Furthermore, they did not significantly differ from M1. In M3 (Strong invariance), in addition to equal factor loadings over time, the intercepts of the manifest indicators were constrained to be equal across measurement occasions. In turn, the models achieved acceptable fits and did not significantly differ from M2. This implies that strong factorial invariance holds in this sample and thus adequately captured the data. Taken together, the results indicate that factor loadings and indicator intercepts of cognitive abilities and personality traits remained invariant across time.

Table 3. *Correlations and Descriptive Statistics*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Paired associates	-	.25	.31	.24	.28	.25	.25	.19	.42	.27	.17	-.06	-.01
2. Story recall	.35	-	.32	.21	.32	.22	.22	.27	.27	.29	.14	-.05	.02
3. Picture recall	.26	.23	-	.18	.31	.25	.17	.11	.47	.25	.11	-.01	.10
4. Number comparison	.15	.06	.12	-	.56	.61	.31	.15	.27	.10	.20	-.08	.18
5. Identical pictures	.23	.14	.20	.39	-	.67	.43	.22	.27	.17	.23	-.04	.14
6. Letter digit substitution	.24	.18	.18	.63	.67	-	.45	.13	.32	.14	.34	-.09	.24
7. Standard matrices	.29	.22	.12	.32	.40	.51	-	.27	.21	.16	.31	-.15	.04
8. Spot-a-word	.24	.28	.11	.07	.29	.21	.36	-	.13	.18	.17	.01	-.09
9. Word list recall	.26	.17	.22	.11	.15	.22	.16	.12	-	.29	.10	-.05	.03
10. Reading span	.35	.29	.23	.15	.27	.25	.30	.27	.26	-	.12	-.08	.06
11. Openness	.15	.02	.02	.01	.15	.17	.26	.16	.01	.08	-	-.17	.27
12. Neuroticism	.04	-.08	.07	.06	.07	.02	-.15	.02	.04	.04	-.11	-	-.37
13. Conscientiousness	-.04	.13	.08	.03	.00	.13	.06	-.11	.00	.03	.03	-.30	-
<i>M</i> (T1)	3.85	14.39	7.44	17.41	18.94	30.71	16.27	32.13	24.79	0.63	19.55	15.22	29.10
<i>SD</i> (T1)	2.84	3.68	1.50	4.33	4.56	6.53	3.62	2.97	8.83	0.16	3.21	4.39	3.82
<i>M</i> (T2)	3.56	13.51	6.88	16.57	17.36	28.71	15.16	31.91	22.96	0.62	19.32	16.21	28.75
<i>SD</i> (T2)	3.05	3.82	1.69	4.65	4.69	6.71	4.03	3.43	10.19	0.24	3.28	4.71	3.91
Range	0–12	0–25	0–12	0–60	0–60	0–75	0–24	0–37	0–27	0–100	0–45	0–60	0–60

Note. $N = 236$. Correlations at T1 are reported below the diagonal, correlations at T2 are reported above the diagonal. Boldface correlations

are statistically significant at $p < .05$ (or lower). Means (*M*), standard deviations (*SD*) and possible ranges of the variables of interest are shown in raw scores.

Table 4. *Measurement Invariance*

Model	χ^2 (df)	CFI	RMSEA [90% CI]	ΔX^2 (df)	Δ Models
Cognitive abilities					
Memory					
M1: Configural invariance	4.88 (5)	1.00	0.000 [0.000, 0.089]		
M2: Weak invariance	6.62 (7)	1.00	0.000 [0.000, 0.077]	1.74 (2)	2–1
M3: Strong invariance	8.72 (9)	1.00	0.000 [0.000, 0.072]	2.09 (2)	3–2
Processing speed					
M1: Configural invariance	14.98*(5)	0.99	0.092 [0.041, 0.147]		
M2: Weak invariance	15.42*(7)	0.99	0.071 [0.020, 0.120]	0.44 (2)	2–1
M3: Strong invariance	15.57 (9)	0.99	0.056 [0.000, 0.101]	0.15 (2)	3–2
Verbal learning					
M1: Configural invariance	25.62*(15)	0.99	0.055 [0.010, 0.090]		
M2: Weak invariance	30.58*(18)	0.99	0.054 [0.016, 0.087]	4.96 (3)	2–1
M3: Strong invariance	30.92 (20)	0.99	0.048 [0.000, 0.080]	0.34 (2)	3–2
Personality					
Openness					
M1: Configural invariance	7.02 (5)	1.00	0.041 [0.000, 0.106]		
M2: Weak invariance	7.58 (7)	1.00	0.019 [0.000, 0.084]	0.56 (2)	2–1
M3: Strong invariance	7.79 (9)	1.00	0.000 [0.000, 0.066]	0.21 (2)	3–2
Neuroticism					
M1: Configural invariance	6.36 (5)	1.00	0.034 [0.000, 0.101]		
M2: Weak invariance	6.89 (7)	1.00	0.000 [0.000, 0.079]	0.53 (2)	2–1
M3: Strong invariance	7.43 (9)	1.00	0.000 [0.000, 0.064]	0.54 (2)	3–2
Conscientiousness					
M1: Configural invariance	7.83 (5)	1.00	0.049 [0.000, 0.111]		
M2: Weak invariance	8.36 (7)	1.00	0.029 [0.000, 0.088]	0.54 (2)	2–1
M3: Strong invariance	9.36 (7)	1.00	0.013 [0.000, 0.075]	0.99 (2)	3–2

Note. χ^2 : chi-square, CFI: comparative fit index, RMSEA: root mean square error of

approximation, 90% CI: 90% confidence intervals for RMSEA, ΔX^2 (df): nested chi-square

difference and difference in degrees of freedom (df), Δ Models: comparison of models.

* $p < .05$.

Rank–Order Stability and Mean–Level Change

Based on the models of strong MI (M3) we found significant rank-order stability in cognitive abilities and personality traits over the 4-year time period (Table 5). The mean rank-order stability index across cognitive abilities using the *r*-to-*z* approach was $r = .76$ and $r = .83$ across personality traits, respectively. In general, longitudinal correlations revealed relatively high levels of rank-order stability.

Based on the models of strong MI (M3), models with freely estimated factor means over time were compared with models in which the factor means were constrained to be equal across the two measurement occasions. Compared to M3 (Table 4), the models of equal means over time in processing speed and neuroticism showed a significant loss of fit, $\Delta\chi^2(1) = 16.81, p < .001$ (processing speed), and $\Delta\chi^2(1) = 7.04, p < .01$ (neuroticism). In other words, processing speed tended to decrease over time, whereas neuroticism tended to increase over time. All other models did not lead to a statistically significant decrease in model fit, indicating that these variables did not change over time. Table 5 displays the mean-level changes, whereas the first measurement occasion was used as a reference with a factor means of zero, that is, factor means at the second measurement occasion reflect deviations from the reference.

Table 5. *Longitudinal Stability and Change*

Model	Rank-order stability (<i>r</i>)	<i>M</i> (<i>SE</i>) T1	<i>M</i> (<i>SE</i>) T2	Mean-level change (ΔM)
Cognitive abilities				
Memory	.89**	0.12 (0.06)	0.05 (0.06)	−0.04
Processing speed	.93**	0.14 (0.06)	0.01 (0.06)	−0.12**
Reasoning	.67**	0.07 (0.06)	0.00 (0.06)	−0.05
Verbal knowledge	.71**	−0.02 (0.12)	−0.01 (0.12)	0.01
Verbal learning	.56**	0.10 (0.06)	0.05 (0.06)	−0.01
Working memory	.52**	0.06 (0.06)	−0.01 (0.07)	−0.04
Personality traits				
Openness	.85**	0.03 (0.05)	0.00 (0.05)	−0.03
Neuroticism	.81**	−0.07 (0.04)	0.01 (0.04)	0.07*
Conscientiousness	.84**	0.01 (0.04)	−0.03 (0.04)	−0.04

Note. *N* = 236. Estimates of rank-order stability (*r*), means (*M*), standard errors (*SE*) and mean-level change (ΔM ; scaled as

mean difference from T1 which was set to zero as reference). Note that means and standard errors reflect z-scores.

p* < .01, *p* < .001.

Cross-Lagged Effects

Cross-lagged models allow estimations of whether levels in one domain are related to previous levels of the other domain and vice versa controlled for initial correlations between the variables and their rank-order stability (Grimm et al., 2012). Table 6 shows the initial and change correlations (i.e., residual correlations) of the cross-lagged models. The initial correlations between cognitive abilities and personality traits indicate only few significant associations. Correlations between the T2 scores reflect the associations between levels in cognitive abilities and levels in personality traits when their initial associations as well as their cross-lagged associations are controlled. The general picture suggests that few change correlations (i.e., correlations between residuals) were found, namely only for openness and processing speed, neuroticism and verbal learning as well as conscientiousness and processing speed.

Table 6. *Initial and Change Correlations*

	Openness		Neuroticism		Conscientiousness	
	Initial	Change	Initial	Change	Initial	Change
Memory	.16	-.06	-.02	-.25	.10	.29
Processing speed	.12	.35	-.01	-.02	.13	.34
Reasoning	.19	.05	-.19	-.15	.07	-.05
Verbal knowledge	.18	.15	.02	.15	-.12	.00
Verbal learning	.07	.12	.04	-.21	-.02	-.10
Working memory	.08	.00	.00	.00	.02	-.03

Note. $N = 236$. Boldface correlations are statistically significant at $p < .05$ (or lower). Correlations between cognitive abilities and personality traits are controlled for age and education.

Effects of cognitive abilities on personality traits. We tested 18 cross-lagged effects of cognitive abilities on personality traits, whereof 1.8% were significant. As displayed in Table 7, higher (lower) levels of reasoning were related to higher (lower) levels in openness four years later ($\beta = 0.116, p = .038, 95\% \text{ CI } [0.02, 0.21]$). The effect size was small. No effects of cognitive abilities on neuroticism and conscientiousness were found.

Effects of personality traits on cognitive abilities. We tested 18 cross-lagged effects of personality traits on cognitive abilities, whereof again one effect was significant. Table 7 shows the cross-lagged personality traits' effects. The level of conscientiousness was significantly related to the level of verbal knowledge after four years, again with a small effect size ($\beta = -0.108, p = .037, 95\% \text{ CI } [-0.19, -0.02]$) All other effects were not significant.

Table 7. *Cross-Lagged Effects for Cognitive Abilities and Personality Traits*

Predictor	Outcome	<i>N</i>	β	95% CI
Memory	Openness	233	0.142	[0.02, 0.26]
	Neuroticism	232	−0.031	[−0.16, 0.10]
	Conscientiousness	232	−0.045	[−0.18, 0.06]
Processing speed	Openness	231	0.092	[0.00, 0.19]
	Neuroticism	230	−0.053	[−0.15, 0.05]
	Conscientiousness	230	0.106	[0.00, 0.21]
Reasoning	Openness	233	0.116*	[0.02, 0.21]
	Neuroticism	232	0.003	[−0.10, 0.10]
	Conscientiousness	232	0.007	[−0.09, 0.11]
Verbal knowledge	Openness	233	0.028	[−0.06, 0.12]
	Neuroticism	232	0.009	[−0.08, 0.10]
	Conscientiousness	232	0.016	[−0.08, 0.11]
Verbal learning	Openness	233	−0.058	[−0.15, 0.03]
	Neuroticism	232	−0.040	[−0.14, 0.06]
	Conscientiousness	232	−0.009	[−0.11, 0.09]
Working memory	Openness	231	0.056	[−0.03, 0.14]
	Neuroticism	230	−0.064	[−0.15, 0.03]
	Conscientiousness	230	−0.039	[−0.13, 0.05]
Predictor	Outcome	<i>N</i>	β	95% CI
Openness	Memory	233	0.150	[0.01, 0.30]
	Processing speed	231	0.067	[0.00, 0.14]
	Reasoning	233	−0.012	[−0.10, 0.08]
	Verbal knowledge	233	−0.035	[−0.13, 0.06]
	Verbal learning	233	0.069	[−0.05, 0.18]
	Working memory	231	0.118	[0.01, 0.23]
Neuroticism	Memory	232	−0.013	[−0.15, 0.12]
	Processing speed	230	−0.074	[−0.14, −0.01]
	Reasoning	232	0.007	[−0.08, 0.09]
	Verbal knowledge	232	−0.033	[−0.12, 0.05]
	Verbal learning	232	−0.012	[−0.12, 0.10]
	Working memory	230	−0.027	[−0.13, 0.08]
Conscientiousness	Memory	232	0.007	[−0.13, 0.14]
	Processing speed	230	0.034	[−0.03, 0.10]
	Reasoning	232	0.020	[−0.06, 0.10]
	Verbal knowledge	232	−0.108*	[−0.19, −0.02]
	Verbal learning	232	0.124	[0.02, 0.23]
	Working memory	230	0.113	[0.01, 0.22]

Note. CI = confidence interval of parameter estimates. Table shows standardized regression

weights with significant cross-lagged paths at $*p < .05$.

4.2.4 Discussion

This study examined cognitive abilities and personality traits and their longitudinal associations in older age over four years. Based on the models of strong MI, we found relatively high rank-order stabilities and stable mean-levels for both core domains. Only few initial and change correlations between cognitive abilities and personality traits were significant. Our results suggest cross-lagged links between (1) reasoning and openness as well as (2) conscientiousness and verbal knowledge, whereas both effect sizes are relatively small. These primary and other findings are discussed in more detail below.

Equivalent Measurement Properties over Time in Older Age

From a psychometric perspective, the measurement of change requires that the cognitive tasks and the personality questionnaire measure the same construct (i.e., cognitive abilities and personality traits) across time. Although this sounds simple, the relationships between tasks or questionnaire items and their underlying constructs may be complex. These associations are typically characterized by a measurement model that needs not to stay constant across time (e.g., when participants reprioritize or reconceptualize the perceived meanings of test items across time). In our study, we established strong MI, a methodological prerequisite that is not often explicitly tested in samples beyond age 70 years, but especially important in older age (cf. Mõttus et al., 2012a), as aging is characterized by manifold changes in different modalities such as cognition, health, and social environment. Strong MI warranted unbiasedness of the latent cognitive abilities and personality traits across measurement occasions. Consequently, the longitudinal comparisons of factor means were deemed to be interpretable as quantitative shifts in invariant measures.

More Stability than Change in Personality in Older Age

Based on strong MI, cognitive abilities and personality traits show relatively high levels of stability across four years in terms of rank-order correlations and factor means. The rank-order stabilities are in line with the few existing longitudinal stability coefficients

reported in previous studies (e.g., Allemand, Zimprich, & Martin, 2008; Hertzog et al., 2003; Möttus et al., 2012a; Roberts & DelVecchio, 2000). Concerning cognitive abilities, it seems that high rank-order correlations in older age support the model of “preserved differentiation” that predict stability of performance differences (Salthouse, 2006). Thus, individuals with higher and lower cognitive reserve differ in their levels of cognitive performance, but their rates of decline in performance are comparable. A possible factor that may contribute to high personality rank-order stability in older age is identity structure (Roberts & DelVecchio, 2000). In addition, personality traits would not describe what they expected to describe (enduring individual characteristics) without high rank-order stability (Möttus et al., 2012a). Taken together, individuals generally retained their relative positions on cognitive abilities and personality traits. But although stability coefficients were relatively high, this does not imply that there are no reliable individual differences in change of cognitive abilities and personality traits.

On the mean-level, processing speed tended to decrease over time, whereas neuroticism tended to increase. The first finding is largely consistent with previous research on cognitive abilities showing a decrease in processing speed in older age (cf. Salthouse & Ferrer-Caja, 2003). The stable mean-levels of the remaining cognitive abilities may be referred to the fact that the investigated sample was relatively healthy and well-educated, and the time interval was rather short. The increase in neuroticism may be surprising in the first instance, because some studies show that neuroticism tends to decrease with age (e.g., Allemand et al., 2008; Roberts et al., 2006). Nevertheless, it should be noted that participants of these studies were between the ages of 50-64 years. Therefore, it may be that neuroticism decreases in early older age, but then increases in later older age. Recent findings suggest that an increase in neuroticism in older age (cf. Wagner, Ram, Smith, & Gerstorf, 2016) may reflect an aging effect (Kandler et al., 2015). In other words, older individuals have to be more cautious of health-risks and dangers of everyday life (i.e., increasing neuroticism) when

their cognitive, physical, and social functionality declines to maintain a comparable level of emotion regulation and well-being (Kandler et al., 2015).

Taken together, the results of this study indicate relatively stable mean levels for almost all cognitive abilities and personality traits in a sample of older adults aged between 66-81 years across a 4-year time period. It may be that there are no substantial changes in the beginning of the seventh decade, but that there may be more pronounced changes later in life, for example within the eighth or ninth decade (Möttus et al., 2012a). The present study confirms the few existing findings and adds additional evidence suggesting relative high stability in healthy older age, even though aging is typically characterized by manifold individual changes in various life domains.

Effects of Cognitive Abilities on Personality Traits in Older Age

Considering cognitive abilities as a potential predictor of personality traits in older age has only been addressed by a few studies while previous research tended to focus on personality traits predicting levels of cognitive abilities (e.g., Curtis et al. 2015; Wettstein, Kuźma, Wahl, & Heyl, 2016). Hence, cross-lagged findings of cognitive abilities on personality traits are informative per se as they extend our knowledge of cognitive abilities predicting personality traits. In the present study, reasoning was the only cognitive ability that was significantly related to openness. As stated earlier, we did not form specific hypotheses for the different cognitive abilities, but rather explore the research topic to form the basis for more conclusive research. When it comes to different cognitive abilities (vs. general cognitive ability), it is important to distinguish between two broad categories at first. Namely, it should be differentiated between *fluid* and *crystallized* cognitive abilities in order to understand cognition-personality relations (Moutafi et al., 2003). Fluid ability involves quick thinking, reasoning, seeing relationships between ideas, approaching new problems, whereas crystallized ability is the accumulation of information of facts, figures, skills and knowledge over time (Brody, 1992). This distinction seems relevant for the interpretation of our findings.

Indeed, it has been suggested that the relationship between openness and fluid abilities is different than the association with crystallized abilities (Moutafi et al., 2003; 2004). That is, individuals with lower fluid abilities (e.g., reasoning) may show more difficulties to handle novel experiences which, in turn, discourages openness. On the other hand, high openness may lead individuals to expand their crystallized abilities (e.g., verbal knowledge). This difference thus refers to the causal direction and means that openness might be influenced by fluid abilities, whereas openness might influence crystallized abilities. In other words, cross-lagged effects of cognitive abilities on openness could be expected for fluid, but not necessarily for crystallized abilities. This is in line with our results as higher (lower) levels of reasoning were related to higher (lower) levels of openness, but there was no relation between verbal knowledge and openness.

Reasoning and openness. A possible explanation for the reasoning-openness finding might be that individuals with lower levels of reasoning have more difficulties to draw conclusions as well as to cope with novel or challenging situations, resulting in lower levels of openness as there is no scope for development. In contrast, older adults with higher levels of reasoning benefit from this cognitive resource, seeking to stimulate and challenge themselves by the exposure to novel experiences. Consequently, they become more curious and show more cognitive interests and ideas what is related to higher levels of openness four years later. Furthermore, a positive relation between reasoning and openness was reported by a cognitive training study (Jackson, Hill, Payne, Roberts, & Stine-Morrow, 2012). In this study, older adults completed a 16-week program in inductive reasoning training and showed higher levels of openness after the training compared to the baseline assessment. Although this finding is not directly comparable as it comes from a training study, it supports evidence for a basic association between reasoning and openness (if there was no basic relationship, there would be no change) as found in our study. Even though the cross-lagged effect found in our study was relatively small, it should be noted that small effects can have serious

consequences too (e.g., Ozer & Benet-Martínez, 2006). Lower reasoning capacity may shape openness in later life which in turn may influence other life outcomes (e.g., well-being). This may be even more pronounced or of higher relevance for cognitively impaired individuals. Moreover, lifespan developmental theory suggests that lifespan dynamics of an increasingly negative gain–loss ratio in cognition (Baltes & Baltes, 1990) constitute a key factor for personality development (Wagner et al., 2016). Therefore, small effects of basic relationships merit the attention to be investigated.

However, further research is required to replicate the associations between different cognitive abilities and openness. The present study did not find any cross-lagged effects of the remaining five cognitive abilities. There might be different methodological and theoretical explanations for the different abilities. For example, it may be that processing speed is unrelated to openness, because one could be curious and open to new ideas independent of how fast (or slow) one processes information four years before.

Null results. For neuroticism and conscientiousness, no cognitive abilities' effects were found. In contrast to our expectations, cognitive abilities were not related to neuroticism (see also Table 7). We have two explanations: First, it may be that the investigated time interval was not appropriate regarding the nature of the association between cognitive abilities and neuroticism and conscientiousness. Although the results of the present study are informative, the present study was restricted to two measurement occasions. Additionally, the time interval between these two assessments was relatively short, but it might also have been too long concerning cognition-personality relations. Time intervals that are too short or too long with regard to the nature of the variables of interest can produce data that might be overly sensitive to measurement errors and carryover effects or insensitive to variability and change (cf. Hertzog & Nesselroade, 2003). Second, it may be that cognitive abilities are related only to different facets of neuroticism or conscientiousness. For example, differences between studies for neuroticism may partly be attributable to differences in the scales (anxiety

and depression vs. impulsivity and anger) used to assess neuroticism (Luchetti et al., 2016). Consequently, cognitive abilities may be differentially associated with different facets of neuroticism (Wilson, Begeny, Boyle, Schneider, & Bennett, 2011). The general picture suggests that levels of cognitive abilities are not related to levels of personality traits four years later, except for reasoning and openness.

Effects of Personality Traits on Cognitive Abilities in Older Age

Again, only one cross-lagged finding with a small effect size was detected. Namely, higher (lower) levels of conscientiousness were related to lower (higher) levels of verbal knowledge four years later. Prior studies have found negative associations between conscientiousness and different cognitive abilities too (e.g., Moutafi et al., 2004; Rammstedt et al., 2016), supporting the intelligence compensation hypothesis which assumes individuals with lower cognitive abilities become more conscientious over time to cope with their lower cognitive abilities (Moutafi et al., 2003). Our result cannot be explained by the intelligence compensation hypothesis, because the intelligence compensation hypothesis refers to the causal relationship that intelligence affects the development of conscientiousness (besides this, we did not find any effects of cognitive abilities on conscientiousness as shown in Table 7). Moutafi and colleagues (2004) postulated that there appears to be no specific theoretical explanation for more conscientious individuals to become less intelligent or for less conscientious individuals to become more intelligent. Indeed, our negative cross-lagged finding seems counterintuitive and is difficult to explain. Further research in this field would be of great help in determining the relation between conscientiousness and verbal knowledge. It might be useful to include possible third variables that may mediate or moderate this relationship.

No further cross-lagged effects of personality traits on cognitive abilities were found. It might be especially surprising that there was no significant cross-lagged effect of openness on crystallized abilities, because openness is often positively linked to them on a cross-

sectional level and due to the “distinction hypothesis” mentioned earlier (cf. Moutafi et al., 2003; 2004). A possible methodological explanation for verbal knowledge might be that it was only measured with the spot-a-word task. It seems more appropriate to measure verbal knowledge using multiple tasks rather than focusing on the performance of a single task. Concerning the “distinction hypothesis”, it may also be that openness is not meaningfully related with verbal knowledge in older age anymore. For instance, openness may lead individuals to expand their crystallized abilities (such as verbal knowledge) only in young and middle adulthood but not in older age. Namely, Moutafi et al. (2003) who suggested that higher openness leads to better crystallized ability investigated a sample aged between 23-64 years. Furthermore, verbal knowledge is supposed to peak at around the ages of 45-54 years. By contrast, our participants were aged between 66-81 years.

Measurement Considerations

Although we expected only small associations between cognitive abilities and personality traits, it is somewhat surprising that we found almost no associations. However, two important points should be noted. First, given that correlations are rather modest within the cognitive domains (about .3); it is difficult to expect stronger correlations between personality and any single cognitive ability. Second, it is important to keep in mind that cognitive tasks measure maximal performance, whereas personality questionnaires measure typical behaviors. It is thus reasonable to scrutinize whether or under which circumstances maximal performance is linked to typical behaviors. As such, future research might pay more attention to this distinction between maximal and typical cognitive processes and personality-related experiences and behaviors. For instance, it may be that the cognition-personality association appears stronger in individuals who realize that their cognitive abilities decline and want to “fight against it” or in individuals who want to improve their cognitive performance. This means, individuals need to be at some point where they reach some personal limit, before they change their behaviors depending on different personality traits,

which not until then influence the strength of the individual cognition-personality association. Future research might explore these two domains on a more similar scale level. Today's technologies provide new opportunities to assess cognition and personality on a day-to-day typical behaviors level. For example, ambulatory assessment methods could be used to measure cognitive and personality-related behaviors in daily life. To be more specific, an intensive longitudinal study could be conducted over two weeks. During this time, older individuals would carry a smartphone provided by the study and report their daily cognitive and personality-related activities at noon and in the evening. Participants would be asked what they did as well as rate different items concerning cognitive activities (e.g., "I read the newspapers"), cognitive problems (e.g., "I forgot a date, a grocery item or my medication"), and personality-related behaviors (e.g., "I enjoyed music or art" for openness, "I felt moody" for neuroticism, "I completed everything that I planned to do" for conscientiousness, "I had an argument with somebody" for agreeableness (reverse coded), and "I talked a lot" for extraversion). Furthermore, they would rate the perception of different cognitive abilities (e.g., memory; cf. Luchetti et al., 2016), and solve brief cognitive tasks on the smartphone (e.g., working memory; cf. Riediger et al., 2014) twice a day. Consequently, cognition would be assessed not only objectively (tasks), but also subjectively like the personality-related behaviors and therefore both domains would be assessed on a similar scale level.

Limitations and Further Future Directions

This study has several strengths, including the longitudinal design, the wide range of assessed cognitive abilities, and the statistical techniques for examining the associations between cognitive abilities and personality traits over time. Although our results are informative, the present study has some limitations that we discuss in the following to encourage appropriate conclusions and inform future replication attempts (cf. Simons Shoda, & Lindsay, 2017). First, it must be cautioned some evidence for selective attrition that compromises the generalizability of our results (e.g., Lindenberger, Singer, & Baltes, 2002;

Siegler & Botwinick, 1979). Our continuer sample consisted of 70% of all T1 study participants, and differed in some variables compared to the dropouts, even though the differences were in the small effect size range. Nevertheless, it should be noted that attrition is a well-known problem in aging research (e.g., McArdle, Hamagami, Elias, & Robbins, 1991) and our dropout rate is comparable with previous research (cf. Wettstein et al., 2016; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003). Moreover, such selectivity bias in longitudinal studies of older adults may also represent selectivity processes of late life where those with lower cognitive abilities, lower personal resource capacities and more health issues die earlier. Second, the sample size of the current study was rather modest and might not suffice for the detection of correlation coefficients smaller than .18. Third, the standard cross-lagged models as used in this article do not disentangle the within-person process from stable between-person differences. An alternative model that separates the within-person process from stable between-person differences through the inclusion of random intercepts is the random-intercept cross-lagged model (cf. Hamaker, Kuiper, & Grasman, 2015; Keijsers, 2016). However, while the standard cross-lagged model requires only two waves of data, the random-intercept cross-lagged model requires at least three waves of data (Hamaker et al., 2015), hence, this model approach cannot be applied to the current data.

Regarding future replication attempts, it must be noted that our sample size was rather small, so the association that we observed might differ in replications on statistical grounds. Nevertheless, we believe our results will be reproducible with healthy older adults from similar subject pools serving as participants, using cognitive tasks and self-report personality measures in the laboratory. We have no reason to believe that the results depend on other characteristics of the participants, materials, or context (cf. Simons et al., 2017).

More research, including larger samples, is needed to learn more about the longitudinal association between cognitive abilities and personality traits. In addition, future studies covering a longer follow-up period and more than two measurement occasions are

desirable, because two assessments may not provide sufficient information on the unfolding of processes and their association over time (Kenny, 2005). Lastly, further studies should use (1) personality questionnaires that allow differentiating between facets, and (2) modern technologies to assess cognitive and personality-related activities on a more similar scale level.

Conclusion

So far, very few studies have examined cognitive abilities and personality traits in tandem in older age. The results of the present study demonstrated relatively high rank-order stabilities and stable mean levels for cognitive abilities and personality traits, except for a decrease in processing speed and an increase in neuroticism. Only two cross-lagged findings with small effect sizes were found. However, it should be noted that also small effects can have consequences, and hence merit the attention to be investigated (Ozer & Benet-Martínez, 2006; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). In general, the two domains of functioning showed a very low degree of commonality in older age. Our results suggest more stability than change in cognitive abilities and personality traits in older age across four years. Taken together, the present study contributes to the research field (1) considering cognitive abilities as predictors of personality traits in terms of cross-lagged effects, and (2) differentiating between six different cognitive abilities.

4.3 Study 3: Cognitive Complaints Mediate the Long-Term Effect of Cognition on Emotional Stability⁷

4.3.1 Introduction

Cognition and personality traits are core domains of individual functioning across the life span. Both domains have in common that they are moderately heritable (cf. Briley & Tucker-Drob, 2017), and develop as a function of brain development, environmental demands, and individual experiences over the life span (e.g., Hofer & Alwin, 2008; Roberts & Mroczek, 2008). However, they show differential developmental trajectories over the lifespan: Cognitive functions (especially fluid abilities) tend to increase throughout early adulthood and then begin to show declines in older age (cf. Craik & Bialystok, 2006). Personality traits tend to stabilize in early to middle adulthood (e.g., Roberts, Walton, & Viechtbauer, 2006), and tend to slightly decrease in late life (e.g., Lucas & Donnellan, 2011; Wagner, Ram, Smith, & Gerstorf, 2016). Previous research showed some empirical evidence for smaller, and to some extent inconsistent cross-sectional and longitudinal associations between cognition and personality (see Curtis, Windsor, & Soubelet, 2015, for a review). Some researchers (e.g., Wettstein, Kuźma, Wahl, & Heyl, 2016) have pointed out that there is a general lack of research in cognition–personality interrelations in older age as well as with regard to factors underlying these relationships. Hence, an important step forward in developing a better understanding of the cognition–personality interrelations is to investigate underlying mechanisms (Curtis et al., 2015). Conceptually, developing a better understanding of the cognition–personality interrelations in older age is important for several reasons. First, it is of interest whether stabilities and changes in one domain (e.g., personality) are related to

⁷A similar version of this study is in press for *Psychology and Aging*. ©2018, American Psychological Association. This paper is not the copy of record and may not exactly replicate the final, authoritative version of the article. Please do not copy or cite without authors permission. The final article will be available, upon publication, via its DOI: 10.1037/pag0000246. Original article: Aschwanden, D., Kliegel, M., & Allemand, M. (in press). Cognitive complaints mediate the association between cognition and emotional stability across 12 years in old age. *Psychology and Aging*.

the other domain (e.g., cognition), because specific personality traits may (a) help older adults to maintain their cognitive levels as they age (Baker & Bichsel, 2006) or (b) serve as a source of vulnerability with regard to cognitive decline (Chapman et al., 2012). Similarly, cognition may be a prerequisite for personality traits to remain stable or to change in older age (cf. Moutafi, Furnham, & Crump, 2003). Knowing which domain has maintenance functions for the other domain may help to train or strengthen this particular domain. Second, existing cognitive or personality interventions may benefit from a better understanding of the cognition–personality interrelations in older age (cf. Stine–Morrow & Basak, 2011), as new insights could provide guidance to develop cognitive interventions for different personality types or personality interventions depending on cognitive characteristics (Graham & Lachman, 2014).

The present study investigated cognitive complaints as a potential underlying mechanism of the bidirectional longitudinal association between cognition and emotional stability across 12 years in healthy older adults. In terms of personality dimensions, we focus on emotional stability for two reasons. On the one hand, the association between cognition and emotional stability seems to be stronger in older than in younger adulthood based on cross–sectional comparisons (Soubelet & Salthouse, 2011). On the other hand, emotional stability may be particularly relevant for cognition in late life because it is considered as a protective factor against the development of mild cognitive impairment (Kuźma, Sattler, Toro, Schönknecht, & Schröder, 2011). In terms of our analytical approach, we examined the bidirectional longitudinal association between cognition and emotional stability mediated by cognitive complaints (see below for our rationale on why focusing on cognitive complaints as mediator). In general, the associations between cognition and personality are rarely analyzed bidirectionally, but this will provide important insights into whether the associations are similar or different. First, we tested whether cognition had an effect on emotional stability, and whether this effect is mediated by cognitive complaints. Considering cognition as a

predictor of personality traits has only been addressed by a few studies (e.g., Curtis et al. 2015, Wettstein et al., 2016), as previous research tended to focus on personality traits as predictors of cognition. Second, we tested whether emotional stability had an effect on cognition, and whether this effect is mediated by cognitive complaints.

Cognition and Emotional Stability

In the current literature, explanations for both directions, that is (a) how emotional stability influences cognition and (b) how cognition influences emotional stability are proposed. For (a), individuals low in emotional stability may experience more anxiety and be more prone to intrusive thinking that, in turn, may impair their cognitive performance in a testing situation (Gold & Arbuckle, 1990; Graham & Lachman, 2012; Moutafi, Furnham, & Tsaousis, 2006). Emotional stability is negatively related to anxiety on both the state (e.g., Moutafi et al., 2006) and trait level (e.g., Jylhä & Isometsä, 2006). Moreover, anxiety negatively affects cognitive performance in older adults (e.g., Salthouse, 2012; Stillman, Rowe, Arndt, & Moser, 2012). It has also been suggested that emotionally unstable individuals may perform worse on cognitive tasks due to distractive and worry-related thoughts (Gold & Arbuckle, 1990; Meier, Perrig-Chiello, & Perrig, 2002) or because of their easily aroused sympathetic nervous system (SNS; Biernacki & Tarnowski, 2011). Likewise, the activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to stress releases hormones such as cortisol, adrenaline, and noradrenaline that can impair cognitive performance (e.g., Lupien, Maheu, Tu, Fiocco, & Schramek, 2007). Furthermore, it may be that chronic stress as experienced by individuals low in emotional stability could cause neuronal damage across time (e.g., Chapman et al., 2012; Jorm et al., 1993). In detail, individuals with lower levels of emotional stability experience more stress in their daily lives (e.g., Bolger & Schilling, 1991; Suls & Martin, 2005) that can lead to prolonged activation of the HPA axis, and therefore excess glucocorticoids (hypercortisolemia). Consequently, hypercortisolemia can accelerate the rate of normative hippocampal atrophy (Sapolsky, 1994).

In addition, emotional instability is positively related to a decline in brain volume (e.g., Jackson, Balota, & Head, 2011). For (b), it may be that decline in cognitive ability causes older adults to become more anxious, with increasing anxiety related to lower emotional stability (Curtis et al., 2015).

The existing body of cross-sectional research on the association between cognition and emotional stability suggests that higher emotional stability is linked with better cognitive performance (see Curtis et al., 2015, for a review). The correlation coefficients that have been reported for associations between different measures of cognition and emotional stability ranged from .16 to .50 (cf. Curtis et al., 2015; Gow, Whiteman, Pattie, & Deary, 2005). Although several studies found links between cognition and emotional stability, other studies did not find significant associations between the two domains (e.g., Jelicic et al., 2003; Salthouse, 2014; Wetherell, Reynolds, Gatz, & Pedersen, 2002). Only very few studies have examined this association longitudinally. Lower emotional stability was associated with faster global cognitive decline over six years (e.g., Wilson et al., 2003; Wilson et al., 2007). Chapman et al. (2012) showed that lower emotional stability was related to worse average cognitive functioning seven years later. Nevertheless, other longitudinal studies reported no significant associations between emotional stability and cognition (e.g., Hultsch, Hertzog, Small, & Dixon, 1999; Jelicic et al., 2003; Wetherell et al., 2002).

To sum up, previous cross-sectional research demonstrated some significant associations between cognition and emotional stability in older age, whereas longitudinal studies are very sparse and the existing results are inconsistent. This inconsistency may be due to differences in methodology across studies, the use of specific populations, the age range within late life considered, the analytic approach, covariates included, and the length of the time interval (cf. Luchetti, Terracciano, Stephan, & Sutin, 2016). Importantly, the question of what mechanisms may drive such a longitudinal relation (and therefore also possibly explain the disparate pattern) remains virtually unaddressed.

Underlying Mechanisms between Cognition and Emotional Stability

Although existing cross-sectional research has established a negative association between low emotional stability and cognition in healthy older adults, little is known about the mechanisms that underlie this relationship even from a cross-sectional perspective. In a sample of young and middle-aged adults, emotional stability was no longer related to intelligence when the effects of test anxiety were removed (Moutafi et al., 2006). Furthermore, it has been shown that individual differences in intrusive thoughts mediated the relationship between emotional stability and performance on attention-demanding cognitive tasks beyond negative affect (Munoz, Sliwinski, Smyth, Almeida, & King, 2013). However, the mean age of this sample was 49 years. Moreover, it has been hypothesized that need for cognition may mediate the relationship between emotional stability and intelligence, with a lack of motivation for cognitive challenge being the link between lower emotional stability and lower intelligence (Furnham, & Thorne, 2013). This means, individuals low in emotional stability tend to avoid cognitive challenges that lead to the development of intellectual abilities, or individuals with a strong motivation for cognitive challenge are not affected by test anxiety that impairs the performance of individuals with lower emotional stability on cognitive tests (Moutafi et al., 2006). In contrast to their expectations, Furnham and Thorne (2013) did not find a significant link between emotional stability and intelligence in a sample of undergraduate students, thus failing to test a possible mediation effect of need for cognition.⁸

So far, very few studies have examined potential mechanisms between cognition and emotional stability. Beyond that, the generalizability of these results is restricted to cross-sectional data and to young as well as middle-aged samples. To our knowledge, there is only one study that addressed these limitations and examined whether sensory impairment

⁸Because the present data set did not include test anxiety, intrusive thoughts, need for cognition or information about the arousal of the sympathetic nervous system or hypothalamic-pituitary-adrenal axis, it was not possible to test for these alternative mediators.

moderated the (cross-sectional and) longitudinal relationship between cognition and emotional stability in advanced older age, that is 72 to 95 years (Wettstein et al., 2016). These results suggest that lower emotional stability was associated with worse cognitive performance four years later in sensory impaired individuals, even after controlling for cognition at baseline, age, education, and chronic conditions. Overall, the mechanisms underlying the association between cognition and emotional stability remain largely uninvestigated. Therefore, our research question revolves around testing a longitudinal mediation design, whether cognitive complaints mediate the association between cognition and emotional stability.

Cognitive Complaints as a Potential Mechanism

Cognitive complaints are negative judgments about one's cognitive performance (Mascherek, Zimprich, Rupprecht, & Lang, 2011). Studies over the past two decades have demonstrated that cognitive complaints increase (e.g., Abson & Rabbitt, 1988; Zarit, Cole, & Guider, 1981), whereas actual cognitive performance on average decreases with advancing age (e.g., Lindenberger, & Baltes, 1994; McDonald-Miszczak, Hertzog, & Hultsch, 1995; Schaie, 1996). Therefore, cognitive complaints might be a mechanism that underlies this relationship particularly in older age.

Studies on the relationship between subjective cognitive complaints and objective cognitive performance have given inconclusive results. Some studies found small to moderate relationships between the two constructs (e.g., McDonald-Miszczak et al., 1995), whereas others did not find any association (e.g., Jorm et al., 1997). Nevertheless, these complaints are often interpreted as indicators of cognitive decline (Dufouil, Fuhrer, & Alperovitch, 2005) and age-related cognitive disorders such as Alzheimer's disease and other forms of dementia (Jonker, Geerlings, & Schmand, 2000; Paradise, Glozier, Naismith, Davenport, & Hickie, 2011). As such, cognitive complaints have become a key element of several diagnostic concepts aiming to identify older adults who might be at a risk of cognitive decline (e.g.,

Kliegel & Zimprich, 2005; Levy, 1994). Moreover, cognitive complaints could be linked to emotional stability (e.g., Kliegel & Zimprich, 2005; Wilhelm, Witthöft, & Schipolowski, 2010). Individuals low in emotional stability may negatively color self-judgments in general and cognitive performance (Mascherek et al., 2011). This is consistent with the “complaint hypothesis” (Wilhelm et al., 2010), suggesting that higher complaints reflect to some extent poor self-image or lack of confidence. In turn, poor self-image and lack of confidence may reflect inappropriate general worry and objectively unjustified complaints that are at least partly irrespective of the frequency or intensity of cognitive failure episodes (Wilhelm et al., 2010).

Taken together, both cognition as well as emotional stability are associated with cognitive complaints. Moreover, previous studies also reported links between cognition and emotional stability as stated earlier. This means, previous research has shown evidence for three links separately, that is between (a) cognition and cognitive complaints, (b) emotional stability and cognitive complaints as well as (c) cognition and emotional stability. We aimed to bring these links together by investigating them in a longitudinal mediation design. As emotional instability may serve as a source of vulnerability concerning lower cognition (cf. Chapman et al., 2012), and cognition may be a prerequisite for emotional stability to remain stable or to change in older age (cf. Moutafi et al., 2003), we examined cognitive complaints as a possible underlying mechanism of this bi-directional relationship.

There are several reasons how or why cognitive complaints might mediate the longitudinal association between cognition and emotional stability and vice versa. For example, it might be that individuals with poorer cognitive test performance may be more prone to report cognitive complaints. It is reasonable to assume that poorer cognition is associated with confusing or forgetting names, phone numbers or reporting difficulties in planning or concentrating (e.g., Dufouil et al., 2005; McDonald-Miszczak et al., 1995). Among these individuals, the experience of cognitive complaints may influence their

emotional stability. To be more specific, individuals who make more negative judgments about their cognition (i.e., higher levels of cognitive complaints) may experience more negative emotions such as anger or anxiety, and to be emotionally unstable (i.e., lower levels of emotional stability). Moreover, it might be that older individuals with lower cognition develop cognitive complaints over time because they have more difficulties to cope with circumstances as well as individuals with higher levels of cognition, resulting in being emotionally unstable. Together, these explanations support the assumption that cognition is a prerequisite for personality traits such as emotional stability to remain stable or to change in older age (cf. Moutafi et al., 2003). Furthermore, it might be that individuals with lower emotional stability are more likely to focus on cognitive problems rather than on successful episodes (Ponds & Jolles, 1996) which then actually leads to poorer cognitive performance.

Based on this reasoning, we expected that cognitive complaints mediate the effect of cognition (predictor) on emotional stability (outcome). We hypothesized that individuals with poorer cognitive test performance report more cognitive complaints what is negatively related to their emotional stability. On the other hand, the alternative pattern can also be predicted based on the available literature; namely that cognitive complaints mediate the effect of emotional stability (predictor) on cognition (outcome). Here, it would be expected that individuals with lower emotional stability are more prone to experiencing cognitive complaints that may impair their cognitive test performance.

Goals of the Present Study

The present study investigated whether cognitive complaints mediate the effect of cognition on emotional stability and vice versa over 12 years. First, we tested whether cognition had an effect on emotional stability, and whether this effect is mediated by cognitive complaints. Second, we tested whether emotional stability had an effect on cognition, and whether this effect is mediated by cognitive complaints. Figure 2 shows the two scenarios through which mediation was tested. We tested the mediation models

longitudinally. In contrast to cross-sectional mediation models, longitudinal mediation models account for the temporal structure that is required to test mediation (cf. Infurna & Mayer, 2015). Cross-sectional mediations would be unable to determine whether cognition influences emotional stability or emotional stability influences cognition or whether both are just interrelated due to other common causes. Hence, cross-sectional mediation can inflate the estimates of mediation and does not provide an accurate picture of mechanisms underlying developmental processes (e.g., Infurna & Mayer, 2015; Maxwell & Cole, 2007). Furthermore, it is important to test longitudinal mediation as the mediator cannot be concurrent with the predictor and must precede the outcome (Lindenberger, von Oertzen, Ghisletta, & Hertzog, 2011; MacKinnon, Fairchild, & Fritz, 2007). Moreover, the mediation model makes theoretical claims about causality; therefore, it requires causally unbiased effects (e.g., Cole & Maxwell, 2003; Infurna & Mayer, 2015; Judd & Kenny, 1981), or in other words, possible confounders need to be considered. An advantage of longitudinal designs is to control for one of the most ubiquitous possible confounders, namely prior levels of the dependent variable (Gollob & Reichardt, 1991). For example, when predicting emotional stability at Time 3 from cognition at baseline (Time 1), regression cannot be used to draw conclusions if there are any unmeasured and uncontrolled exogenous variables that correlate with cognition (predictor) and influence emotional stability (outcome). Similarly, in longitudinal mediation models, one must control for the dependent and mediator variable at baseline (Cole & Maxwell, 2003). Otherwise, the estimates of the path of interest will be spuriously inflated.

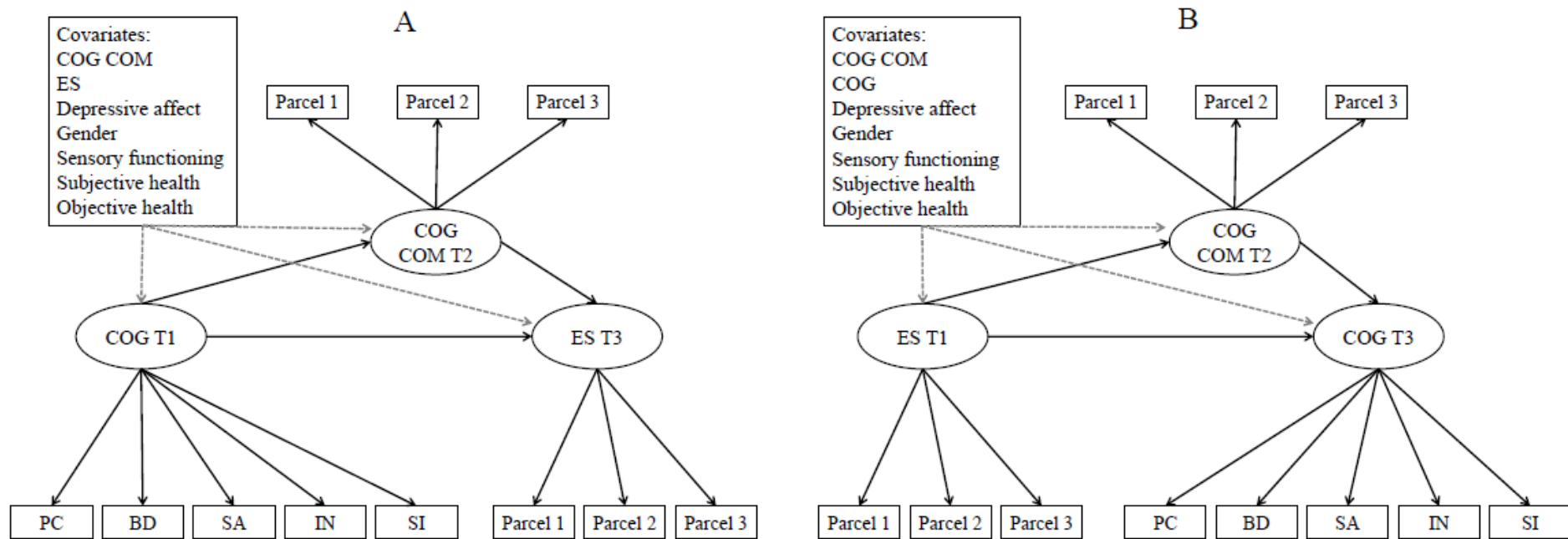


Figure 2. *Simplified Illustration of the Longitudinal Mediation Models*

Notes. COG = cognition, PC = picture completion, BD = block design, SA = spatial ability, IN = information, SI = similarities, COG COM = cognitive complaints, ES = emotional stability. When taking covariates into account, we controlled for baseline levels of the mediator and outcome variable, depressive affect, gender, sensory functioning, subjective and objective health.

4.3.2 Methods

Participants

We used archival data from the Interdisciplinary Longitudinal Study on Adult Development (ILSE; e.g., Allemand, Schaffhuser, & Martin, 2015; Allemand, Zimprich, & Martin, 2008; Sattler et al., 2015) to examine our research goals. The study was carried out in accordance with the Declaration of Helsinki and approved by the ethics committee of the University of Heidelberg. In ILSE, participants come from two age cohorts, one including individuals born in 1930–1932, and the other comprised of individuals born in 1950–1952. The observation period of ILSE was 12 years, including three measurement occasions. The assessments were conducted in 1994 (Time 1; T1), 1998 (Time 2; T2), and 2006 (Time 3; T3). For the current study, only individuals from the older cohort (i.e., born in 1930–1932) were included as our focus was on older age. The first data wave (T1) consisted of 500 older adults (born in 1930–1932). Thereof, 300 individuals participated at all three measurement occasions and had complete data records for the variables of interest. For the current data analyses, we included all 500 participants and accommodated missing data using Full Information Maximum Likelihood estimation procedures.⁹ At T1, the mean age of the sample was 62.97 years ($SD = 0.91$, range = 60–64 years; 52% male). Of the participants, 71.8% were married, 2% lived with a partner, 10.2% were widowed, 8.2% were divorced, 1.6% were separated, 5% were single, and 1.2% did not report on their marital status. The mean level of education was 1.52 ($SD = 0.91$), whereas education was assessed with an ordinal variable including the years of education (1 = <10 years, 2 = 11–12 years, 3 = 13–15 years, 4 = >15 years). The mean of depressive affect was 1.73 ($SD = 0.36$) on a scale ranging from 1 (never) to 4 (always). On average, participants reported no problems with sensory functioning (i.e., hearing and vision; $M = 0.84$, $SD = 0.13$, scale = 0–1). Furthermore, average objective health

⁹ We also ran all analyses including only the 300 individuals who participated at all three measurement occasions and had complete data records for the variables of interest. The results changed minimally, but not concerning the gist. These results are available upon request.

was 4.53 ($SD = 0.88$) on a scale from 1 (very bad) to 6 (very good). The mean of subjective health was 3.40 ($SD = 1.44$) on a scale from 1 (insufficient) to 6 (very good).

To test for differences between those who dropped out and those who continued the study, dropouts ($n = 200$) were compared with continuers ($n = 300$). Continuers were slightly more satisfied with their health (Cohen's $d = .30$), more emotionally stable ($d = .20$), and they reported less depressive affect ($d = -.25$) than dropouts. Furthermore, continuers showed slightly better performance in the cognitive tasks Picture Completion ($d = .22$), Block Design ($d = .37$), Spatial Ability ($d = .40$), Information ($d = .33$) than dropouts. There was a group difference with respect to the cognitive task Similarities with continuers showing a better sum score ($d = .55$). The groups did not significantly differ regarding their age ($d = .15$), education ($d = .10$), and cognitive complaints ($d = .11$). Although continuers and dropouts differed significantly in most variables (except for age, education, and cognitive complaints), these differences reflect small effects (except for the cognitive task Similarities which reflects a moderate effect; Cohen, 1988). Attrition is a well-known problem in aging research (e.g., Lindenberger, Singer, & Baltes, 2002; McArdle, Hamagami, Elias, & Robbins, 1991; Siegler & Botwinick, 1979), and it should be noted that selectivity bias in longitudinal studies of older adults may represent selectivity processes of late life where those with lower cognition, lower resource capacities and more health problems die earlier.

Measures

Cognition. We investigated cognition on a general level by considering established cognitive tests covering a broad range of cognitive functions. Cognition was assessed using five different manifest indicators, namely, Picture Completion, Block Design and Spatial Ability, Information, and Similarities.

First, the Picture Completion task is a subtest of the German Wechsler Adult Intelligence Scale–Revised (WAIS–R; Tewes, 1991). Participants were required to mention details that were missing on 17 pictures of simple objects (e.g., a car with a missing wheel).

Participants were given 20 seconds to mention the missing detail for each picture. Correct answers were scored with one point. Correct answers were added to form a total score of Picture Completion (possible range: 0–17).

Second, the Block Design task is a subtest of the WAIS–R (Tewes, 1991). Participants were required to reproduce abstract patterns using nine colored blocks within a given maximum time limit. For every correct solution within the maximum time limit, two or four points were scored (depending on the complexity of the abstract pattern). Two or three additional points (depending on the complexity of the pattern) were given if the time to reproduce the pattern correctly fell below certain time limits. The nine item scores were added to form a total score of Block Design (possible range: 0–51).

Third, the Spatial Ability task consists of geometrical figures taken from the German test battery “Leistungsprüfsystem” (LPS; Horn, 1983). Participants were required to count the number of surfaces in 40 different three-dimensional images of geometrical figures. Participants were given three minutes to work on the task. Correct answers were scored with one point. Correct answers were summed to form a total score of Spatial Ability (possible range: 0–40).

Fourth, the Information task is a subtest of the WAIS–R (Tewes, 1991). Participants were required to answer a total of 24 questions from different knowledge domains (e.g., what is an ode?). Correct responses were scored with one point. Correct responses were summed up to form a total score of Information (possible range: 0–24).

Fifth, the Similarities task is a subtest of the WAIS–R (Tewes, 1991). Participants were required to name what two concepts had in common (e.g., zoo and library). In total, there were 16 pairs of concepts. Correct solutions were scored with one or two points depending on the quality of the answer. Correct answers were added to form a total score of Similarities (possible range: 0–32).

The estimates of internal consistency (Cronbach's alpha) of the general cognition factor based on the sample of 500 participants were as follows: .82 (T1), .82 (T2), and .80 (T3). The omega hierarchical estimates (Zinbarg, Revelle, Yovel, & Li, 2005) were .73 (T1), .77 (T2) and, .69 (T3). The internal consistencies of cognition ranged from acceptable to good.

Cognitive complaints. Subjective cognitive complaints were measured with six items from the Nuremberg Self-Assessment List (NSL; Oswald & Fleischmann, 1995). These six items assess cognitive problems and were selected based on previous literature (cf. Martin & Zimprich, 2003; Mascherek & Zimprich, 2011). Participants were asked to report cognitive problems in several domains of everyday life (e.g., confusing names, phone numbers, dates or having difficulties to follow the train of thought of others). Items were rated on a 4-point Likert-type scale ranging from 1 (completely wrong) to 4 (completely true). The estimates of internal consistency (Cronbach's alpha) were as follows: .76 (T1), .83 (T2), and .81 (T3). The omega hierarchical estimates (Zinbarg et al., 2005) were .61 (T1), .71 (T2), and .67 (T3). The internal consistencies of cognitive complaints ranged from acceptable to good.

Emotional stability. Emotional stability was measured using 12 items of the German version of the NEO-Five-Factor Inventory (NEO-FFI; Borkenau & Ostendorf, 1993). The items were rated on a 5-point Likert-type scale ranging from 0 (strongly disagree) to 4 (strongly agree). Cronbach's alpha were .77 (T1), .80 (T2), and .80 (T3), whereas the omega hierarchical estimates (Zinbarg, et al., 2005) were .61 (T1), .68 (T2), and .65 (T3). The internal consistencies of emotional stability ranged from acceptable to good.

Potential confounders. We included gender, depressive affect, sensory functioning, objective and subjective health as potential confounders because they share common associations with cognition, cognitive complaints and emotional stability (e.g., Kliegel & Zimprich, 2005; Kliegel, Zimprich, & Eschen, 2005, Wettstein et al., 2016). The inclusion of confounders allows to more stringently testing the mediation effects, thus enhancing the

robustness of the results. *Gender* was coded as 0 for male, and 1 for female. *Depressive affect* was measured using a 20-item self-rating depression scale (SDS; Zung & Zung, 1986). The items were rated on a 4-point Likert-type scale ranging from 1 (never) to 4 (always). Cronbach's alpha was .78 (T1), the omega hierarchical estimate (Zinbarg et al., 2005) was .53 (T1). The internal consistencies of depressive affect ranged from acceptable to good. *Sensory functioning* consisted of two items concerning participants' hearing and vision (i.e., "Did you or do you have problems with hearing?", and "Did you or do you have problems with your vision?"). A dichotomous scale (0, 1) was used for both items. A mean score of the two items was created where lower scores indicate sensory impairment. *Objective health* comprised an anamnesis, a blood analysis, a geropsychiatric assessment, and a medical checkup conducted by one to two trained study geriatricians (see Miche, Elsässer, Schilling, & Wahl, 2014, for more details). The professionals aggregated the data and rated the participants' state of health on 6-point scale. Answer options ranged from 1 (very bad) to 6 (very good). *Subjective health* was measured with one item where participants rated their current health situation 1 (insufficient) to 6 (very good). For all potential confounders, we used data from T1, and included them as manifest variables in the analyses.

Statistical Procedures

Our statistical analyses consisted of several steps. First, we established longitudinal measurement models. Second, we tested these models for longitudinal measurement invariance. Third, we ran the longitudinal mediation models (a) without and (b) with confounders.

Longitudinal measurement models. We used longitudinal structural equation modeling (SEM; McArdle & Nesselroade, 2014) to investigate our research goals. First, longitudinal measurement models were established for cognition, cognitive complaints, and emotional stability. Cognition was estimated as a latent construct consisting of five manifest indicators (i.e., cognitive tasks as mentioned earlier) at each measurement occasion. For cognitive

complaints and emotional stability, parcels were created to form manifest indicators following the item-to-construct balance technique (Little, Cunningham, Shahar, & Widaman, 2002). Correlated residual variances were allowed for the matching parcels at T1, T2, and T3 (Marsh & Hau, 1996).

Longitudinal measurement invariance. To ensure that the latent constructs of interest are comparable over time (Meredith & Horn, 2001), longitudinal measurement invariance (MI) of the latent measures of cognition, cognitive complaints, and emotional stability was established. As older age is a phase of susceptibility to individual and environmental changes as well as non-normative events (Baltes, Lindenberger, & Staudinger, 2006), it seems particularly important to establish MI. It may be that participants tend to change their internal standards of perceptions across 12 years, because of accompanying changes that aging brings with it. Our goal was to establish strong MI (Little, 2013). We first tested an unconstrained measurement model of configural invariance (M1) that longitudinally specified the relationship between manifest indicators and the latent constructs. Second, a model of weak MI (M2) was tested by setting the factor loadings equally over time. The factor variances were freely estimated over time. Third, a model of strong MI (M3) was tested which requires equal factor loadings and equal indicator intercepts over time. The factor means were freely estimated over time. Establishing strong MI allows for meaningful comparisons of means, covariances, and variances over time.

Longitudinal mediation. The mediation model offers an explanation how or why two variables are related, where a mediating variable is hypothesized to be intermediate in the association between a predictor and an outcome (Fairchild, MacKinnon, Taborga, & Taylor, 2009). In mediation analysis, three types of effects are commonly discussed: total effects, direct effects, and indirect effects (cf. Cole & Maxwell, 2003). The total effect is the sum of the direct and indirect effects. Direct effects refer to the effects of the predictor on the outcome. Indirect effects refer to the role of a third variable in mediating the effect of the

predictor on the outcome. First, we considered longitudinal mediation models without confounders. Second, we considered possible confounders to determine whether temporal ordering and other variables influenced the associations. We included the previous assessments of the mediator and outcome variable, depressive affect, gender, sensory functioning, objective and subjective health as potential confounders.

In addition to p -values, we also provide 95% confidence intervals (CI) when reporting the longitudinal mediation models. CIs contain information about the size of an effect and its precision, thus being more informative than p -values alone (Cohen, 1994). CIs for total, direct, and indirect effects in all mediation models are based on bias-corrected bootstrapping (number: 10,000; see MacKinnon, Lockwood, & Williams, 2004). The scores of our variables of interest were converted into z scores (e.g., Schaie, Willis, & Caskie, 2004; Soubelet & Salthouse, 2010, 2011) to facilitate the comparison between different cognitive data types and self-report scales. Analyses were conducted with Mplus 7 (Muthén & Muthén, 1998–2015), and we applied full information maximum likelihood (FIML). To evaluate goodness of fit of the models, the chi-square (χ^2), comparative fit index (CFI), and root mean square error of approximation (RMSEA) as well as its 90% CIs were examined. CFI values above .97 and RMSEA values below .06 are considered to reflect a good fit, whereas CFI values above .93 and RMSEA values below .08 are acceptable (Browne & Cudeck, 1993; Byrne, 1994; Hu & Bentler, 1998). The model comparison was based on the standard fit indices RMSEA, CFI, standardized root-mean-square residual (SRMR), and Tucker Lewis Index (TLI).

4.3.3 Results

Longitudinal Measurement Invariance

Table 8 presents descriptive statistics and zero-order correlations among the variables of interest at T1 and T3. For cognitive complaints, data from T2 were correlated with the variables of interest, as it is the measurement occasion of interest concerning the longitudinal mediation. To establish MI of our latent measures, we first started with the least restrictive

model (M1: Configural invariance) that constrains manifest indicators to load on the same factor over time. As shown in Table 9, all models achieved acceptable fits as judged by the CFI and RMSEA. Second, factor loadings were constrained to be equal over time (M2: Weak invariance). These more restrictive models achieved acceptable fits too. Furthermore, they did not significantly differ from M1 as reflected by the nested chi-square difference in Table 9. Next, the intercepts of the manifest indicators were constrained to be equal over time (M3: Strong invariance). In turn, the models achieved acceptable fits. The M3 models of cognition, cognitive complaints, and emotional stability did not significantly differ from M2. These results indicate that strong MI holds over time with respect to all latent measures. Thus, factor loadings and indicator intercepts of cognition, cognitive complaints, and emotional stability remained invariant across time.

Table 8. *Correlations and Descriptive Statistics*

Variables	1	2	3	4	5	6	7
1. Picture completion	–	.48	.41	.52	.52	–.20	–.32
2. Block design	.48	–	.60	.42	.42	–.14	–.22
3. Spatial ability	.53	.65	–	.46	.43	–.19	–.31
4. Information	.57	.46	.49	–	.60	–.17	–.31
5. Similarities	.47	.45	.52	.58	–	–.14	–.24
6. Cognitive complaints	–.11	–.15	–.16	–.19	–.16	–	.50
7. Emotional stability	–.26	–.22	–.29	–.30	–.19	.46	–
<i>M</i> (T1)	11.73	26.90	21.40	15.61	24.94	1.88	2.56
<i>SD</i> (T1)	3.86	8.17	6.56	4.81	5.50	0.65	0.58
<i>M</i> (T2)	12.00	24.29	20.48	16.00	24.09	2.00	2.51
<i>SD</i> (T2)	3.67	8.57	6.73	4.59	6.23	0.68	0.57
<i>M</i> (T3)	11.79	24.13	19.84	16.27	24.50	2.02	2.46
<i>SD</i> (T3)	4.08	8.11	6.86	4.49	6.03	0.70	0.56
Range	0–17	0–51	0–40	0–24	0–32	1–4	0–4

Note. $N = 500$. Correlations at T1 are reported below the diagonal, correlations at T3 are

reported above the diagonal. For cognitive complaints (mediator), data from T2 was

correlated with the variables of interest. Boldface correlations are statistically significant at

$p < .05$ (or lower). Means (*M*), standard deviations (*SD*) and possible ranges of the

variables of interest are shown in raw scores. The means for emotional stability are shown

in reverse: Higher scores indicate lower levels of emotional stability and lower scores

indicate higher levels of emotional stability.

Table 9. *Measurement Invariance*

Model	χ^2 (df)	CFI	RMSEA [90% CI]	$\Delta\chi^2$ (df)	Δ Models
Variables					
Cognition					
M1: Configural invariance	207.84***(72)	0.97	0.06 [0.052, 0.071]		
M2: Weak invariance	216.57***(80)	0.97	0.06 [0.049, 0.068]	8.73 (8)	2–1
M3: Strong invariance	217.63***(88)	0.97	0.05 [0.045, 0.063]	1.06 (8)	3–2
Cognitive complaints					
M1: Configural invariance	31.33**(15)	0.99	0.05 [0.023, 0.070]		
M2: Weak invariance	32.81*(19)	0.99	0.04 [0.013, 0.060]	1.48 (4)	2–1
M3: Strong invariance	32.98 (23)	0.99	0.03 [0.000, 0.051]	0.18 (4)	3–2
Emotional stability					
M1: Configural invariance	20.66 (15)	1.00	0.03 [0.000, 0.054]		
M2: Weak invariance	22.11 (19)	1.00	0.02 [0.000, 0.045]	1.46 (4)	2–1
M3: Strong invariance	22.24 (23)	1.00	0.00 [0.000, 0.035]	0.12 (4)	3–2

Note. $N = 500$. χ^2 = chi-square; CFI = comparative fit index; RMSEA = root mean square error

of approximation; 90% CI = 90% confidence intervals; $\Delta\chi^2$ = nested chi-square difference; Δ df = difference in degrees of freedom; Δ Models = comparison of models.

* $p < .05$, ** $p < .01$, *** $p < .000$.

Longitudinal Mediation Models

Results of the two¹⁰ longitudinal mediation models are shown in Table 10 and 11. Bias–corrected bootstrapped confidence intervals are only available for the unstandardized (but not for the standardized) results of the models (Muthén & Muthén, 1998–2015, p. 727). Thus, we report both unstandardized and standardized estimates and standard errors, and bias–corrected bootstrapped confidence intervals for unstandardized results. In addition, we standardized the effects of the unstandardized results in order to report effect sizes. These effect sizes were taken by dividing the effect estimate by the standard deviation of the outcome variable (MacKinnon, 2008; Infurna & Mayer, 2015). Last, we compared the models (emotional stability–cognition model with covariates vs. cognition–emotional stability model with covariates) based on their fit indices.

Effects of cognition on emotional stability. Table 10A shows the effects of cognition on emotional stability without confounders. The total effect of cognition on emotional stability was 0.53, $SE = 0.09$, $p < .000$. The effect size was medium to large. Lower levels of cognition were associated with lower levels of emotional stability over 12 years. The effect size of the direct effect of cognition on emotional stability was in the small to medium range. We also observed that cognitive complaints did mediate the effect of cognition on emotional stability (indirect effect = 0.13, $SE = 0.04$, $p < .000$), but that the effect size was small (0.17).

Table 10B shows the results of the effects of cognition on emotional stability with confounders. Similar to the previous model, we found a significant total as well as direct effect when we accounted for confounders (total: 0.22, $SE = 0.08$, $p < .01$; direct: 0.18, $SE = 0.07$, $p < .01$). Both effect sizes were small. On average, showing lower levels of cognition was associated with reporting less emotional stability 12 years later. Cognitive complaints did mediate this effect (indirect effect = 0.04, $SE = 0.02$, $p < .05$). The effect size was 0.05,

¹⁰A more elegant analytic approach might be to simultaneously include all variables in one model. Because the model fit of the simultaneous model was not acceptable, we decided to test two separate models including a model comparison based on the model fit indices.

suggesting that although cognitive complaints mediated the effect of cognition on emotional stability, the strength or evidence of the link is very small.

Effects of emotional stability on cognition. Results of the longitudinal mediation models without and with confounders are shown in Table 11A and 11B. We found a significant total effect of emotional stability on cognition without taking confounders into account ($0.36, SE = 0.09, p < .000$). The effect size was medium. Furthermore, a significant direct effect was found ($0.29, SE = 0.11, p < .01$) with an effect size in the small to medium range (0.41). Lower levels of emotional stability were related to lower levels of cognition. However, cognitive complaints did not mediate this association (indirect effect: $0.07, SE = 0.06$). When testing the total and direct effects of emotional stability on cognition in the appropriate longitudinal model that accounted for temporal ordering and prior confounds, both effects were reduced to non-significance (see Table 11B). Because the total and direct effects were not significant, the indirect effect was neither.¹¹

Model comparison. To compare which model fits better, we checked the model fit indices of both models. The models did not differ with regard to RMSEA, but the cognition–emotional stability model yielded better values of CFI, SRMR, and TLI. However, these differences were minimal and the inference could not be secured statistically. Therefore, it cannot be concluded that one model fits the data better than the other.

¹¹A reviewer suggested to test the mediation models for all Big Five personality traits. Hence, we tested two longitudinal mediation models (both directions) for each trait separately. The results are available upon request. In summary, we had to reject some models due to their unacceptable model fits, and we found no significant total, direct or indirect effects at all.

Table 10. *Effects of Cognition on Emotional Stability*

Effect of	Emotional stability: standardized results		Emotional stability: unstandardized results			
	Estimate	SE	Estimate	95% BCCI	SE	Effect size
A: without confounders						
Cognition						
Total	0.478***	0.060	0.534***	[0.378, 0.720]	0.086	0.68
Direct	0.361***	0.065	0.403***	[0.247, 0.577]	0.083	0.51
Indirect	0.117***	0.033	0.131***	[0.062, 0.218]	0.039	0.17
B: with confounders						
Cognition						
Total	0.202**	0.066	0.218**	[0.080, 0.373]	0.075	0.29
Direct	0.168**	0.064	0.181*	[0.047, 0.332]	0.072	0.24
Indirect	0.035*	0.016	0.037*	[0.010, 0.082]	0.018	0.05

Note. $N = 500$. BCCI = bias–corrected confidence intervals. Bias–corrected bootstrap sample size = 10,000. The total effect is the sum of the direct and indirect effects. Direct effects refer to the effects of cognition on emotional stability. Indirect effects refer to the role of cognitive complaints in mediating the effect of cognition on emotional stability. Confounders that were included in Part B were baseline levels of the dependent and mediator variable, depressive affect, gender, sensory functioning, subjective and objective health.

* $p < .05$, ** $p < .01$, *** $p < .000$.

Table 11. *Effects of Emotional Stability on Cognition*

Effect of	Cognition: standardized results		Cognition: unstandardized results			
	Estimate	<i>SE</i>	Estimate	95% BCCI	<i>SE</i>	Effect size
A: without confounders						
Emotional stability						
Total	0.335***	0.068	0.360***	[0.201, 0.533]	0.085	0.51
Direct	0.270**	0.095	0.290**	[0.088, 0.510]	0.107	0.41
Indirect	0.065	0.056	0.070	[-0.041, 0.205]	0.061	0.10
B: with confounders						
Emotional stability						
Total	-0.067	0.077	-0.074	[-0.254, 0.092]	0.088	-0.10
Direct	-0.072	0.081	-0.080	[-0.269, 0.091]	0.092	-0.11
Indirect	0.005	0.081	0.005	[-0.011, 0.050]	0.013	0.01

Note. $N = 500$. BCCI = bias-corrected confidence intervals. Bias-corrected bootstrap sample size = 10,000. The total effect is the sum of the direct and indirect effects. Direct effects refer to the effects of emotional stability on cognition. Indirect effects refer to the role of cognitive complaints in mediating the effect of emotional stability on cognition. Confounders that were included in Part B were baseline levels of the dependent and mediator variable, depressive affect, gender, sensory functioning, subjective and objective health.

** $p < .01$, *** $p < .000$.

4.3.4 Discussion

The aim of this study was to examine the bidirectional association between cognition and emotional stability and the mediating effect of cognitive complaints in healthy older adults. Two possible predictions were tested and then compared. First, we tested whether older individuals with poorer cognitive test performance show lower levels of emotional stability 12 years later and whether this effect is mediated by cognitive complaints. This pattern was confirmed by testing a longitudinal mediation model that controlled for baseline emotional stability, baseline cognitive complaints, depressive affect, gender, sensory functioning, objective and subjective health. Second, we tested whether older individuals with lower levels of emotional stability show poorer cognitive test performance 12 years later and whether this effect is mediated by cognitive complaints. In contrast to the previous pattern, our findings do not support a mediation effect of cognitive complaints on the relationship between emotional stability and cognition. Several important conceptual conclusions are suggested by those findings.

The finding that lower levels of cognition are associated with lower levels of emotional stability over 12 years is per se informative, because far very little attention has been paid to cognition as a predictor of emotional stability in older age (e.g., Curtis et al. 2015, Wettstein et al., 2016). Moreover, this finding is consistent with the lifespan developmental theory suggesting that lifespan dynamics of an increasingly negative gain–loss ratio in cognition (Baltes & Baltes, 1990) constitute a key factor for personality development (Wagner et al., 2016). Furthermore, cognitive complaints mediate the link between cognition and emotional stability. A possible explanation for this finding may be that compromised cognitive resources constrain and contribute to more cognitive complaints, thus leading to lower emotional stability. For example, older individuals with lower levels of cognition may have more difficulties to cope with situations that require cognitive resources in daily life. To illustrate, these individuals find it difficult to concentrate on reading the newspapers and

complain about their ability to concentrate. Related to these complaints, they report lower levels of emotional stability. This explanation supports the assumption that reduced cognitive reserve capacity can be expected to shape personality trait development later in life (Wagner et al., 2016). Our results highlight the importance of investigating cognition as a predictor of personality traits in older age. Not only emotional instability may be a risk factor for cognitive decline (e.g., Luchetti et al., 2016) or dementia (e.g., Low, Harrison, & Lackersteen, 2013), cognitive resources may also serve as a protective factor for emotional stability in late life.

Regarding the effect size, the strength of the mediating effect of cognitive complaints was relatively weak. However, it should be noted that the associations between cognition and personality are rather weak in general (e.g., Aschwanden, Martin, Allemand, 2017), and the investigated time interval of 12 years was relatively long with regard to this matter.

Furthermore, also small effects can have consequences, and hence merit the attention to be investigated (Ozer & Benet-Martínez, 2006; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007).

A practical implication based on our findings might be that individuals with poorer cognitive functioning and reporting cognitive complaints should be identified, because they are at risk for experiencing lower emotional stability. Cognitive interventions may help to maintain cognition (cf. Kelly et al., 2014) and everyday functioning (e.g., Gross, Rebok, Unverzagt, Willis, & Brandt, 2011), and thus have positive side effects on personality traits (e.g., Jackson, Hill, Payne, Roberts, & Stine-Morrow, 2012; but see also Sander, Schmiedek, Brose, Wagner, & Specht, 2017) such as emotional stability. Specifically, a combined cognitive–personality intervention that improves cognitive performance and reduces cognitive complaints may be successful to maintain emotional stability in older age. For family members and friends, it might be easier to observe cognitive complaints than lower cognition in daily life. Therefore, cognitive complaints may represent an identifier of those who are at risk of experiencing lower emotional stability due to their cognitive functioning. Moreover,

interventions may consider identifying at-risk individuals by using cognitive complaints' surveys or interviews. The target of the intervention would be on cognitive performance as it precedes cognitive complaints (i.e., cognitive training). At the same time, older individuals should be encouraged to preventively work on their emotional stability because it is influenced by cognitive complaints (i.e., personality intervention). Furthermore, emotional stability was found to be the primary trait domain of all Big Five traits showing changes as a result of interventions (Roberts et al., 2017). This combined approach could be implemented within a computer-based or smartphone-based intervention at home. For instance, individuals would solve cognitive tasks and engage in exercises that are tailored to enhance emotional stability behaviors every morning. The cognitive training should be adaptive at skill levels with the goal that individuals would feel challenged but not overwhelmed (Payne, Jackson, Noh, & Stine-Morrow, 2011). The emotional stability exercises could include simple tasks such as doing something good for oneself or reappraise a negative experience. Short interventions, lasting days rather than weeks, may be unlikely to improve cognition and to change emotional stability. Future research is required to establish the applicability of a combined cognitive-personality intervention and its duration to be effective, especially in view of the small effect size of the mediating effect of cognitive complaints. But the first and critical step, showing that the associations between cognition, cognitive complaints and emotional stability are evident not only in separate models but also in a longitudinal mediation design, has now been taken.

With regard to the inverse direction, lower levels of emotional stability are related to lower levels of cognition 12 years later when ignoring possible confounders. Contrary to possible predictions, cognitive complaints are not the underlying mechanism by which the relationship between emotional stability and cognition occurs. Although previous work suggested that individuals low on emotional stability may negatively color self-judgments in general and cognitive performance (e.g., Mascherek et al., 2011), our results suggest that

individuals with lower emotional stability are not more prone to experiencing cognitive complaints and thus showing poorer cognitive performance. There are two likely explanations. First, our sample consisted of healthy, cognitively non-impaired individuals. It is possible that a longitudinal association between emotional stability, cognitive complaints and cognition is only evident in individuals who suffer from mild cognitive impairment or dementia. Put differently, it can be assumed that as long as individuals with lower emotional stability are healthy and report some minor cognitive hassles only, there is no longitudinal association, but it might be different for individuals who suffer from serious cognitive problems. It seems that poorer cognitive performance needs to be recognized first by the individual, before judging negatively about one's cognitive ability. Second, cognitive complaints are one of many possible mediators at play, such as test anxiety (Moutafi et al., 2006) and intrusive thoughts (Munoz et al., 2013), which show similar associations with cognition and emotional stability at least in young and middle-aged adults. Unfortunately, the present study did not include test anxiety or intrusive thoughts. For further studies, it may be useful to assess whether the effect of emotional stability on cognition is also mediated by these two factors in older adults. However, the effect of emotional stability on cognition vanished when we controlled for temporal ordering and prior confounds. This indicates that the effect is apparent when other variables are taken into account and supports previous research reporting null findings between emotional stability and cognition (e.g., Hultsch et al. 1999; Jelicic et al., 2003; Wetherell et al., 2002). We offer three possible explanations. First, it may be that the investigated time interval of 12 years was not appropriate regarding the nature of the effect of emotional stability on cognition. It is possible that the nature of the association differs between (a) cognition-emotional stability, and (b) emotional stability-cognition. For example, it may be that the time interval of 12 years was appropriate for cognition-emotional stability, but it may be shorter or longer for emotional stability-cognition because of different mechanisms that may underlie the direction of these relations.

So, the distance between measurement occasions must be chosen separately for the direction that will be investigated. Time intervals that are too long or too short can produce data that might be overly sensitive to measurement errors and carryover effects or insensitive to variability and change (cf. Hertzog & Nesselroade, 2003). Second, it may be that only specific facets of emotional stability are related to different cognitive abilities (cf. Luchetti et al., 2016; Wilson, Begenly, Boyle, Schneider, & Bennett, 2011). Using 12 items of the NEO–FFI (Borkenau & Ostendorf, 1993), we were not able to differentiate between facets, what is an important issue for future research. Third, a possible explanation could be that the effect of emotional stability on cognition is only present in later older age, but not in early older age. Hertzog, Kramer, Wilson, and Lindenberger (2009) pointed out that the mean age of studies observing an association between emotional stability and cognition was over 70 years, whereas studies finding no association investigated samples with a mean age under 70 years, consistent with the idea that the detrimental effects of psychological distress are cumulative and therefore most evident in later older age. Furthermore, the authors identified other factors that may be partly responsible for the null results in emotional stability–cognition literature, such as having fewer participants ($N < 500$) and lower follow–up participation ($< 85\%$). Hence, the present study is characterized by all these factors (baseline age under 70, $N = 500$, follow–up participation rate $< 85\%$) that may have contributed to find no effect of emotional stability on cognition.

From a methodological point of view, the effects of the associations of interest differed by the tested models. Concerning the mediating effect of cognitive complaints on the association between cognition and emotional stability, the effect size was relatively small across both models (without and with confounders). Nevertheless, it was clearly reduced when tested appropriately with confounders. Moreover, we found no significant effect of emotional stability on cognition in the model with confounders. This shows that the effects and effect sizes are dependent on the type of design used, and emphasizes that temporal

ordering and controlling for (prior) confounds need to be held for scientists to draw conclusions from mediation (Infurna & Mayer, 2015).

Limitations and Future Directions

The current study has a number of strengths, including the use of a late-life longitudinal sample, the consideration of cognition as a predictor, testing longitudinal mediation models, and identifying cognitive complaints as an underlying mechanism between cognition and emotional stability. Another important strength was that the sample represented a narrow age cohort (60–64 years at T1), meaning that our associations of interest could be associated with a very specific age range, and that the associations were not confounded by variation in chronological age. However, our study also has a number of limitations. We expect some constraints on the generalizability of our findings that we consider below in order to encourage appropriate conclusions and inform future replication attempts (cf. Simons, Shoda, & Lindsay, 2017). It might be that an unmeasured relevant confounder would change parts of our findings, although we attempted to include all relevant confounders in our longitudinal mediation models. Furthermore, it is possible that more than only one factor underlies the association between cognition and emotional stability. Such factors should be identified and included in future multiple mediation models, in addition to cognitive complaints to test and determine which are most pertinent. For instance, heightened hypothalamic–pituitary–adrenal axis activity might be such a factor because it can be linked to emotional stability and cognition (Wilson et al., 2011). Furthermore, chronic stress might be another factor that should be taken into account (Scott et al., 2015).¹² Moreover, the present study examined whether levels in cognition were predicted by levels of emotional stability and vice versa. As such, we were interested “in the basics” of possible cognition–emotional stability relations, and we strictly met the requirements of a longitudinal mediation

¹²As suggested in the review process, we included sensory functioning and objective health as possible mediators in addition to cognitive complaints. Results (available upon request) showed that neither the indirect effect of sensory functioning nor objective health was significant, but only the indirect effect of cognitive complaints for the cognition–emotional stability model.

(the predictor must precede the mediator, the mediator must precede the outcome). Though, it would be interesting to focus on changes in cognition and emotional stability in future investigations. It may be that changes in emotional stability may be more predictive for cognition than levels of emotional stability at one point in time and vice versa. Latent change score (LCS) models (cf. Ferrer, & McArdle, 2010; McArdle, 2009) offer the possibility to test these ideas. Likewise, further studies are required to test whether emotional stability varies by different cognitive domains.

Regarding future replication attempts, we believe the results will be reproducible with healthy older adults from similar subject pools serving as participants, and using cognitive tasks and self-report emotional stability measures in the laboratory. We have no reason to believe that the results depend on other characteristics of the participants, materials, or context (cf. Simons et al., 2017).

Conclusion

Taken together, this study has shown that cognitive complaints mediate the relationship between cognition and emotional stability in only one direction. Our findings indicate that cognition precedes cognitive complaints, and cognitive complaints precede emotional stability, but not vice versa. Overall, this study strengthens the idea that even personality traits such as emotional stability that use to be relatively stable across the lifespan (e.g., Lucas, & Donnellan, 2011) may be shaped by broad-based functional levels of cognition late in life, and that cognitive complaints play a role in terms of possible mechanisms. Cognitive complaints may serve as an identifier to prevent older adults from experiencing lower emotional stability if they could participate in an intervention. On the other hand, individuals low in emotional stability do not seem to be prone to experience cognitive complaints and therefore showing poorer cognitive performance 12 years later. Briefly, the present study contributes to the research field of the associations between cognition and personality by (1) considering cognition as a predictor of emotional stability,

and (2) identifying cognitive complaints as a unidirectional mediator of this relationship in older age. Nevertheless, further studies need to be carried out to learn more about the longitudinal association between cognition and emotional stability and further potential underlying mechanisms.

4.4 Study 4: Behaviors Related to Cognition and Personality in Daily Life¹³

4.4.1 Introduction

Assessing human functioning and behavior in laboratory, observational, and daily life settings is central in psychological sciences. Two core domains of human functioning are personality traits and cognition. In laboratory settings, personality traits are usually measured by questionnaires where individuals describe their behaviors and attitudes, while cognition is usually assessed by different cognitive tasks where individuals show what they are able to perform. In daily life settings, personality-related behaviors are usually measured by daily diaries provided via mobile phones. In terms of cognition, cognitive behaviors such as cognitive engagement and cognitive complaints can also be assessed by daily diaries. When assessing these behaviors on a daily basis, it is important to distinguish the level of analysis because behaviors may differ between and within individuals in daily life (Fleeson & Jayawickreme, 2015). For instance, some individuals might enjoy music (i.e., open behavior) more than others (between-person level), but their tendency to enjoy and listen to music may also vary from day to day (within-person level). Likewise, some individuals might engage more often in cognitive activities (e.g., watching an educational or documentation movie) than others in their leisure time, but a certain individual may also watch two educational movies on one day and no educational movie on the next day and so on. Similarly, people might differ regarding the expressions of their neurotic behaviors (e.g., being moody) and cognitive complaints (e.g., forgetting a grocery item). These expressions may vary from day to day for one specific individual as well.

But how often do older adults complain about their cognitive functioning in daily life? And how often do older adults engage in cognitive activities? Are these cognitive behaviors related to open or neurotic behaviors? Most of the existing studies focused on the between-

¹³A similar version of this study has been submitted to the *Journal of Personality*. This chapter may not exactly replicate the original version. It is not the copy of record. Original article: Aschwanden, D., Luchetti, M., & Allemand, M. (submitted). *Personality-related behaviors are associated with cognitive engagement and cognitive complaints in daily life of older adults*.

person associations between personality and cognitive-related constructs, and less emphasis has been put on these associations at the within-person level. The present study thus investigated two different associations in daily life, that is the association between (a) open behaviors and cognitive engagement, and (b) neurotic behaviors and cognitive complaints among older adults. We aimed to provide new knowledge about these manifestations in daily life by describing them at the within-person level.

What We Know So Far

Empirical evidence has shown positive associations between openness and cognitive engagement at the between-person level (cf. Ackerman & Goff, 1994; Soubelet & Salthouse, 2010). Openness is characterized as the general tendency to be curious, creative, sensitive to aesthetics, and open to new ideas and experiences (Costa & McCrae, 1992a). Cognitive engagement can be defined as “an individual’s aversion or attraction to tasks that are intellectually taxing” (Ackerman, Kanfer, & Goff, 1995, p. 276). For example, an intellectually taxing activity may be learning a new language (Mascherek & Zimprich, 2012). Previous research suggested substantial positive correlations between openness and cognitive engagement (i.e., $r = .44-.70$; Ackerman & Goff, 1994). Although researchers discussed on whether openness and cognitive engagement assess the same or different constructs (Ackerman & Goff, 1994; Goff & Ackerman, 1992; Rocklin, 1994), Ackerman and Goff (1994) provided evidence for the differentiation of these two constructs because of the lack of substantial correlations between cognitive engagement and several facets of openness. Thus, openness can be considered a broader personality trait that encompasses more dimensions (e.g., affective, sensory, attitudes, and preferences) than cognitive engagement (Soubelet & Salthouse, 2010). Investment theories, particularly the model of the personality-intelligence interface (Chamorro-Premuzic & Furnham, 2004), postulate that individuals with high levels of openness engage more in intellectual activities that provide learning opportunities, and that this engagement improves cognitive functioning (i.e., crystallized abilities). Furthermore,

higher levels of openness predicted higher levels of cognitive engagement in older adults (Hogan, Staff, Bunting, Deary, & Whalley, 2012), suggesting that more open adults tend to engage more often in intellectual activities, such as learning about new topics or philosophizing about things.

Previous research also showed positive links between neuroticism and cognitive complaints (Kliegel & Zimprich, 2005; Lane & Zelinski, 2003; Ponds & Jolles, 1996; Wilhelm, Witthöft, & Schipolowski, 2010). Neuroticism is characterized as the general tendency to experience negative emotions such as anger, anxiety, and depression, and to be emotionally unstable (Costa & McCrae, 1992a). Cognitive complaints can be defined as negative judgments about one's cognition (Mascherek, Zimprich, Rupprecht, & Lang, 2011). Correlation coefficients for the association between cognitive complaints and neuroticism ranged around $r = .49$ (cf. Kliegel & Zimprich, 2005). This means, individuals who experience more negative emotions such as anger or anxiety (i.e., higher neuroticism) tend to make more negative judgments about their cognition (i.e., higher levels of cognitive complaints). A possible explanation might be that neurotic individuals focus on cognitive problems rather than on successful episodes (Ponds & Jolles, 1996). Furthermore, neurotic individuals may negatively color self-judgments in general and with respect to their cognitive performance (Mascherek et al., 2011). This interpretation is consistent with the "complaint hypothesis" (Wilhelm et al., 2010): High cognitive complaint scores may be an expression of poor self-image or lack of confidence, and reflect inappropriate general worry and objectively unjustified complaints. As such, self-reports of cognitive complaints might be biased by negative self-relevant schemata that increase the activation of failure episodes. This then leads to preferred memory retrieval of such events (Brewin, 2006) that are at least partly irrespective of their absolute or relative frequency or intensity (Wilhelm et al., 2010). Assessing cognitive complaints on a daily basis may at least partly antagonize this bias. Namely, the retrieval of the self-report over a short time period (e.g., one day) may be less

biased compared to the retrieval in a laboratory setting where participants typically are asked to rate their cognitive complaints over a longer period of time (e.g., “lately” in Kliegel, Zimprich, & Eschen, 2005; or “compared to earlier” in Mascherek et al., 2011). Moreover, cognitive complaints increase with advancing age (e.g., Abson & Rabbitt, 1988; Zarit, Cole, & Guider, 1981), whereas actual cognitive performance on average decreases (e.g., Lindenberger, & Baltes, 1994; Schaie, 1996).

What We Need to Know

The majority of the above-mentioned studies have focused on the between-person associations between personality and cognitive-related constructs. For example, if one wanted to test the hypothesis that an open-minded attitude is critical for engagement in cognitive activities and performance, the typical approach has been to determine whether more open individuals are cognitively more engaged and show better cognitive performance than less open participants. However, determining a relationship at the between-person level does not necessarily translate to how these variables are related at the within-person level (e.g., Mroczek, Spiro, & Almeida, 2003; Nezlek, 2011). This means, analyses of between-person associations yield knowledge of important trait variables that distinguish individuals from one another, whereas analyses of within-person associations yield insights into the dynamic relations between variables and their dependence on situational circumstances (Bolger, Davis, & Rafaeli, 2003; Bolger & Laurenceau, 2013). Distinguishing between-person from within-person variability in behaviors related to personality and cognition is important for understanding their stability and change over days. For cognition-personality research, it is important to comprehend what it means for one person to vary from another, and what it means for a person to vary from himself or herself (cf. Mroczek et al., 2003).

Investigating associations at the daily between-person level helps to better understand how people think and behave, and how changes in thoughts and behaviors are manifested in daily life and not only in the laboratory (cf. Allemand & Mehl, 2017; Wrzus, & Mehl, 2015).

Furthermore, this approach provides information about the short-term dynamics (e.g., from day to day) and underlying processes of change or maintenance that typically cannot be covered in laboratory studies (cf. Bolger et al., 2003; Reis & Gable, 2000), and as they occur in addition to long-term developmental processes (Diehl, Hooker, & Sliwinski, 2015; Nofhle & Fleeson, 2010). Briefly, it is essential to grasp daily between-person differences in order to observe human individuality in daily life. Knowledge about such individuality can lead to individually designed intervention strategies. However, it is equally important to recognize within-person variation because it may give insights into the changing behaviors and states of an individual's life. Studying associations at the within-person level is important for at least two more reasons. First, it determines whether the between-person associations are limited to a description of co-occurrences of differences between individuals or can be included in the characterization of the ongoing, internal psychological functioning of individuals. Second, it tests the potential implication of between-person correlations, for example that individuals can become cognitively more engaged by behaving more open, or become cognitively less complaintive by behaving less neurotic, respectively. This means, if this is a potential route to self-improvement, it must be the case that changes within an individual in open behaviors (or neurotic behaviors, respectively) are associated with changes in that individual in cognitive engagement (or cognitive complaints, respectively). Accordingly, possible intervention strategies may be derived and tested in order to strengthen these associations or to promote adaptive change (e.g., older individuals should be encouraged to maintain their open behaviors if they are related to cognitive engagement or they should be encouraged to work on their neurotic behaviors if they are related to cognitive complaints).

About the Present Study

The present study investigated two separate research questions. First, we examined the daily associations between open behaviors and cognitive engagement. Second, we investigated the daily associations between neurotic behaviors and cognitive complaints. It

should be noted that what we know about these associations is largely based on trait measures of openness, neuroticism, cognitive engagement, and cognitive complaints, whereas the present study employed measures of personality-related and cognitive behaviors in daily life. However, this is a reasonable approach as there is a systematic connection between traits and behaviors. It is namely a core assumption of trait theory that the existence of relatively stable trait attributes of individuals predicts their behavior across time and situations (Johnson, 1997; Kenrick & Funder, 1988). Prior research has shown that the Big Five personality traits are systematically related to behaviors (e.g., Ching et al., 2014; Fleeson & Gallagher, 2009; Sherman, Rauthmann, Brown, Serfass, & Jones, 2015). For instance, open individuals act in a more self-revealing way and neurotic individuals behave more nervous (cf. Fleeson & Gallagher, 2009 for a meta-analysis see; Fleeson & Wilt, 2010).

Although between-person and within-person analyses can yield different results (Kievit, Frankenhuys, Waldorp, & Borsboom, 2013), a certain isomorphism across these analyses is possible. We expected that individuals who report more open behaviors do also report more cognitive engagement in daily life (between-person). Furthermore, a positive within-person association was hypothesized. Specifically, on days when older adults report more open behaviors, they engage more in cognitively demanding activities on that day. The artistic imagination and aesthetic, independent, and nonconforming aspects of open behaviors (cf. DeRaad, Hendriks, & Hofstee, 1992; Johnson, 1994) on a specific day may be critical drivers of broader patterns of cognitive activity that lead to cognitive engagement on that day. Moreover, we hypothesized that individuals who report more neurotic behaviors complain more about their cognition in daily life (between-person), and on days when older adults report more neurotic behaviors, they complain more about their cognition on that day (within-person). The core aspects of neurotic behaviors (e.g., anxiety, worry, anger, and depression; Costa & McCrae, 1992b) on a specific day may negatively color a person's cognition and lead to cognitive complaints on that day.

We focused on self-reported cognitive behaviors rather than to employ cognitive tasks because we aimed to investigate naturally occurring behaviors in daily life at the within-person level. In contrast, cognitive tasks measure maximal performance where individuals show what they are able to perform. But in daily life is usually no need to perform at the maximum in order to manage one's daily duties. Individuals manage their daily life by engaging in different activities and behaviors. Indeed, these activities and behaviors require some cognitive effort, but usually individuals are not at their cognitive limit while performing them. Furthermore, open and neurotic behaviors were examined in association with cognitive variables separately as done in prior studies.

4.4.2 Methods

Participants

Participants were drawn from the RHYTHM (Realizing Healthy Years Through Health Maintenance) study in Switzerland. RHYTHM was designed to examine how older individuals actively use and orchestrate multiple stabilization processes and maintain behaviors in their daily life. A total of 136 healthy older individuals (41.2% male) were recruited via advertisements in two national newspapers and a database of older adults who are interested in study participations. The mean age of the sample was 70.45 years ($SD = 6.27$, range = 60-91 years). Of the participants, 3.7% attended secondary school with lower school track, 15.4% attended secondary school with higher school track, 3.7% attended secondary school with the Matura graduation (high school), 25.7% attended a university of applied sciences, 20.6% attended university, and 30.9% reported to have another educational background (e.g., vocational training). None of the participants showed signs of (a) cognitive impairment as assessed by the Mini Mental State Examination (MMSE scores < 24 ; Folstein, Folstein, & McHugh, 1975) or (b) depression as measured by the General Depression Scale (GDS scores < 18 ; Hautzinger & Bailer, 1993). Perceived health was measured with 12 items concerning the participants' current health situation (Ware, Kosinski, & Keller, 1996). On

average, participants reported relatively good health, that is $M = 1.32$ ($SD = 0.34$) on a scale from 1 = *excellent* to 6 = *very poor*.

All methods and procedures were approved by the ethics committee for psychological and related research of the University of Zurich. All participants gave their written informed consent prior to study participation.

Procedure

The study lasted a total of 12 days and included three phases: pre-daily assessment (day 1), daily assessments (from day 2 to day 11), and post-daily assessment (day 12). On day 1, participants came to the laboratory for a screening session and completed a series of cognitive tasks and self-report questionnaires (e.g., trait personality). They were also provided with an Android mobile phone and were instructed on how to use the device during the daily assessment phase¹⁴. An initial group of approximately 20 participants began the study in the same week, a second group started the study two weeks later, a third group started two weeks after the second group and so on.

The daily assessment phase consisted of multiple active and passive assessments per day. Participants were triggered to answer questions on various domains of functioning three times a day on their mobile phone by a ring tone. Rings were timed randomly within three fixed time periods each day, that is between 08:00-11:00 am (morning), 01:00-04:00 pm (afternoon), and 06:00-09:00 pm (evening). The rings were at minimum 110 minutes apart from the next one. If participants did not respond to a ring, they were reminded after up to a total of ten times. Moreover, participants could decide to delay responding and were then reminded again by a ring tone (within the same time period). The software movisensXS version 4474 (movisens GmbH, 2016) was employed to run the daily questions on the Android mobile phones. Participants were advised to call a study hotline if they experienced

¹⁴Note that daily assessments started on day 1 when participants were provided with the mobile phone. However, day 1 data were excluded from the current analyses because some participants received the mobile phone in the morning, whereas others not until the evening, thus missing measurement prompts.

problems concerning the mobile phone or had other questions. On day 12, participants attended a final laboratory session during which they returned the mobile phones, filled in the same questionnaires completed at day 1 along with a post-study feedback survey. They were paid 150 Swiss Francs (approx. USD 153) for their participation.

Importantly, not all questionnaires were prompted three times a day to minimize participant burden and to maintain participant motivation (Reis & Gable, 2000). Given that our variables of interest were included at the end of day only, the present data analyses are based on the evening measurement occasions. The compliance of participants was very high in the present study, they completed at minimum 89% of the evening measurement occasions, and 92% of the total mobile phone assessments.

Measures

Daily personality-related behaviors. Every evening, participants rated ten items to report retrospectively on their daily behaviors related to the personality trait openness and ten items related to the personality trait neuroticism. The items come from the daily behavior checklist (DBQ; Church et al., 2008) in which participants check “yes” (1) or “no” (0) for each behavior to indicate whether or not they performed this behavior that day. These behaviors are valid indicators of the respective Big Five dimensions (cf. Church et al., 2008). We created a daily summary variable using the mean of each ten items for openness and neuroticism. High scores then indicate more open behaviors (e.g., enjoying music or arts, experiencing intensive feelings, listening to a person who shares other values and opinions) and more neurotic behaviors (e.g., experiencing a lot of stress, being moody, being jealous¹⁵), respectively.

Daily cognitive engagement. Every evening, participants also rated a total of nine items to report retrospectively on their daily cognitive engagement. We used a shortened version of the Typical Cognitive Engagement (TIE) questionnaire (Goff & Ackerman, 1992).

¹⁵Strictly speaking, these items refer to emotions. However, we refer to them as behaviors to be in line with Church et al. (2008).

The items were selected based on their feasibility in daily life, that is, a balance between rather abstract and rather concret items was chosen. For example, the item “I focused on an abstract problem” was considered as a rather abstract item. In contrast, the item “I watched an educational or documentation movie” was considered as a rather concret item. The items were “I avoided a complicated duty that required thinking” (reverse coded), “I felt competent because I concerned myself with a difficult duty”, “I enjoyed thinking about a complicated problem”, “I philosophized about things”, “I enjoyed thinking about an issue even when the results of my thoughts have no effect on the outcome of the issue”, “I focused on an abstract problem”, “I watched an educational or documentation movie”, “I listened to a speech”, and “I was bored” (reverse coded). Participants were asked to answer the items on a Likert scale ranging from 0 (*strongly disagree*) to 6 (*strongly agree*). High scores indicate a high engagement in intellectual demanding activities. A daily summary variable was created using the mean of these nine items. Following the recommendations of Bolger and Laurenceau (2013), we tested for the within-person reliability of this multi-item scale. We gauged the reliability coefficient omega based on the multilevel confirmatory factor analysis (MCFA; Muthén & Asparouhov, 2011). Omega allows each of the items to have unique loadings and error variances to the underlying construct being measured. The within-person reliability estimate omega was .94. Hence, we can conclude that, for the particular items and particular days chosen in our study, it is possible to reliably distinguish individuals in terms of their patterns of change over time.

Daily cognitive complaints. Participants rated a total of four items to report retrospectively on their daily cognitive complaints on each evening measurement occasion. The items were adapted from the Nuremberg Self-Assessment List (NSL; Oswald & Fleischmann, 1995). The items were selected based on their feasibility in daily life (i.e., balance between rather abstract and rather concret items). For example, the item “I had difficulties to focus on a task or to follow a conversation” was considered as a rather abstract

item. In contrast, the item “I misplaced or lost an object (e.g., keys, glasses)” was considered as a rather concret item. The items were “I had difficulties to remember a name”, “I forgot something (e.g., birthday, grocery item, medication)”, “I misplaced or lost an object (e.g., keys, glasses)”, and “I had difficulties to focus on a task or to follow a conversation”. Participants rated the items on a Likert scale ranging from 0 (*strongly disagree*) to 6 (*strongly agree*). High scores then indicate more cognitive complaints. A daily summary variable was created using the mean of these four items. The within-person reliability estimate omega was .79. Again, for the particular items and particular days chosen in our study, it is possible to reliably distinguish individuals in terms of their patterns of change over time.

Covariates. We included age, education, and the general cognitive status (i.e., MMSE score) as potential confounders in our statistical analyses because they share common associations with cognitive engagement (e.g., Soubelet & Salthouse, 2010), cognitive complaints (e.g., Kliegel & Zimprich, 2005), and the personality traits openness and neuroticism (cf. Curtis, Windsor, & Soubelet, 2015; Luchetti, Terracciano, Stephan, & Sutin, 2016). In addition, we included time (day) as a covariate. This variable reflected the ordinal time point (day) of the daily assessments (0 to 9). We did not expect systematic mean-level changes in our variables, though reactivity effects and individual differences over time might be likely to be observed (cf. Bolger & Laurenceau, 2013). Furthermore, we included trait openness as a covariate of the association between open behaviors and cognitive engagement. Likewise, trait neuroticism was added as a covariate when testing the link between neurotic behaviors and cognitive complaints. Trait openness and neuroticism were measured using the Big Five Inventory (John, Naumann, & Soto, 2008) on day 1 (pre-daily assessment). The items were rated on a 7-point Likert scale ranging from 0 (*strongly disagree*) to 6 (*strongly agree*). For openness (10 items), Cronbach’s alpha was .75, whereas the omega hierarchical estimate (Zinbarg, Revelle, Yovel, & Li, 2005) was .40. For neuroticism (8 items),

Cronbach's alpha was .84, and the omega hierarchical estimate was .78. The internal consistencies of both measures ranged from acceptable to good.

Statistical Analyses

In the present study, daily associations between (a) open behaviors and cognitive engagement, and (b) neurotic behaviors and cognitive complaints were investigated. This means, our data exhibited a nested structure: Daily observations (Level 1) were nested within participants (Level 2). For this reason, we used multilevel modeling (Bolger & Laurenceau, 2013; Raudenbush & Bryk, 2002; Singer & Willett, 2003) to investigate our research questions. Multilevel modeling is an extension of the regression approach in which multiple error terms are used to partitioning variance between each level of the structure in the data (Snijders & Bosker, 1999). In this way, associations both within and between each level of structure can be analyzed without violating standard assumptions of independence. Thus, multilevel modeling helps to disentangle how variables wax and wane together within a person over multiple measurement occasions.

The analyses were performed in two steps. First, unconditional random-intercept-only models without predictors were estimated to calculate the intraclass correlation coefficients (ICCs). The ICC represents the ratio of between-person to within-person variance (Nezlek, 2011). If the ICC is low, there is no need to use multilevel modeling as the individuals do not differ from each other in a meaningful way. Second, conditional random-intercept-random-slope models were tested, this means age, education, general cognitive status, trait openness or neuroticism, respectively (all grand-mean centered), and time (centered at zero) were added to investigate the associations between (a) open behaviors and cognitive engagement, and (b) neurotic behaviors and cognitive complaints. In addition, we examined possible cross-level interactions in the conditional random-intercept-random-slope models (Raudenbush & Bryk, 2002). In the present two-level data structure, a cross-level interaction occurs when a relationship between two level 1 (within-person) variables varies as a function of a level 2

(between-person) variable (Nezlek, 2011). Hence, we investigated whether our level 2 variables age, education, general cognitive status, trait openness or neuroticism, respectively, moderated the associations of interest. In our analyses, we included a between-person version and a within-person version of the predictors to control for the between-person effects and to truly examine the within-person variation (cf. Bolger & Laurenceau, 2013). The between-person versions correspond to the person-means of the predictors. The within-person versions of the predictors were computed by subtracting the person-means from the grand-mean centered variables.

The statistical models were estimated using Mplus 7 (Muthén & Muthén, 1998-2015), and missing data was accommodated using Full Information Maximum Likelihood (FIML) estimation procedures. In addition to p -values, we also provide 95% confidence intervals (CI). CIs contain information about the size of an effect and its precision, thus being more informative than p -values alone (Cohen, 1994). The proportion of variance explained was quantified by the summary statistic pseudo R^2 . This is an alternative to the conventional summary statistic R^2 that is not designed for how multilevel models decompose total outcome variation into multiple variance components (Singer & Willett, 2003). Pseudo R^2 is the proportional reduction in residual variance between two models, therefore, it is an indicator of how much added predictors explain unexplained outcome variation. The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) provided information about the goodness of fit.

4.4.3 Results

Analyses were performed on 1,216 to 1,355 available observations, out of theoretically possible 1,360 observations (136 participants \times 10 days). Missing data ranged from 0.4% to 10.6% depending on the variables of interest. Table 12 presents the descriptive statistics and correlations among the variables of interest. Note that correlation coefficients are provided separately for within-person and between-person variables.

Within-person correlations. Results showed that open behaviors were positively related to cognitive engagement and cognitive complaints (Table 12). Furthermore, a positive correlation between neurotic behaviors and cognitive complaints was found. All correlations were in the expected direction, except for the positive within-person association between open behaviors and cognitive complaints. Though the reason is not clear, it may be that open individuals tend to report more openly cognitive problems or they are more sensitive or attentive to possible cognitive change they experience with aging.

Between-person correlations. Associations with age suggested that older participants showed lower scores on the MMSE and trait openness (Table 12). Moreover, a higher MMSE score was associated with higher levels of education. In turn, higher levels of education were related to higher levels of trait openness. Finally, trait openness and neuroticism were negatively correlated.

Table 12. *Descriptive Statistics and Correlations*

Variables	<i>M</i>	<i>SD</i>	Range	Within-person correlations				Between-person correlations				
				1	2	3	4	5	6	7	8	9
1. Open behaviors	0.29	0.18	0-1	-								
2. Cognitive engagement	3.09	0.88	0-6	.42***	-							
3. Neurotic behaviors	0.12	0.09	0-1	.05	-.05	-						
4. Cognitive complaints	0.97	0.98	0-6	.06*	.05	.09***	-					
5. Age	70.45	6.24	60-91					-				
6. Education	4.64	0.66	0-7					-.02	-			
7. MMSE	27.79	1.15	0-30					-.24**	.24**	-		
8. Trait openness	4.25	0.79	0-7					-.24**	.36***	.01	-	
9. Trait neuroticism	2.05	1.09	0-7					.06	-.02	-.07	-.27**	-

Note. $N_1 = 136$ participants, $N_2 = 1,249$ to 1,355 observations. MMSE = Mini Mental State Examination; *M* = mean; *SD* = standard deviation. The

range refers to the possible range of variables, except for age that represents the actual age range. Education was assessed on an ordinal scale

ranging from 0 (no education) to 7 (university). Note that correlation coefficients are provided separately for within-person and between-person

variables.

* $p < .05$., ** $p < .01$., *** $p < .001$.

Unconditional random-intercept-only models (Step 1)

The random effect variance of open behaviors indicated significant variation at the within-person level ($B = .16, p < .001$). The ICC of open behaviors was .52, indicating that 52% of the total variance lied between-persons and 48% lied within-persons. For neurotic behaviors, significant variation at the within-person level ($B = .01, p < .001$) was found. The ICC of neurotic behaviors was .27, hence indicated that 27% of the total variance lied between-persons and 73% lied within-persons. The variation at the within-person level was significant for both cognitive variables, i.e., engagement ($B = .39, p < .001$) and complaints ($B = .49, p < .001$). The ICC of both cognitive variables was .50, thus indicated that 50% of the total variance for each of these variables lied between-persons and 50% lied within-persons. In sum, all ICCs were relatively high and justified the use of multilevel modeling.

Conditional random-intercept-random-slope models (Step 2)

Tables 13 and 14 show the fixed and random effects of the conditional models¹⁶. All intercepts and slopes were modeled as random effects (Bolger & Laurenceau, 2013).

Open behaviors and cognitive engagement. We tested the association between open behaviors and cognitive engagement, and controlled for age, education, general cognitive status, trait openness, and time. With respect to the results, the variable “slope” in Table 13 is of focal interest for this paper. This is the random slope that we have named “slope” and is defined by the within-person regression of cognitive engagement on open behaviors (cf. Finch & Bolin, 2017). The fixed effect of the slope was 1.03 ($B = 1.03, SE = 0.17, p < .001, 95\% \text{ CI } [0.699, 1.364]$), indicating that within individuals, days of more open behaviors were significantly related to more cognitive engagement behaviors on the same days, and that days of fewer open behaviors were significantly related to fewer cognitive engagement behaviors on the same days. Likewise, daily open behaviors were positively associated with daily

¹⁶The estimates are unstandardized coefficients, because standardized coefficients are not available in Mplus for models with random effects. This is because it is unclear how to standardize when the variance of the dependent variable varies over observations and there is no single variance/covariance matrix (Muthén & Muthén, 2014).

cognitive engagement at the between-person level (see person-mean open behaviors in Table 13). This suggests that an increase of one-unit in open behaviors was associated with an increase of 2.35 in daily cognitive engagement ($B = 2.35$, $SE = 0.34$, $p < .001$, 95% CI [1.679, 3.024]). With regard to the covariates, trait openness was significantly related to daily cognitive engagement, whereas age, education, general cognitive status, and time were unrelated to daily cognitive engagement. The predicted increase in the intercept of cognitive engagement was 0.14 for a one-unit increase in trait openness ($B = 0.14$, $SE = 0.07$, $p < .05$, 95% CI [0.006, 0.264]). This suggests that for every one-unit increase in trait openness, there is a 0.14 increase in daily cognitive engagement.

Cross-level interaction. In addition, we observed a significant cross-level interaction: Age (between-person variable) moderated the effect of open behaviors on cognitive engagement (within-person relationship). This means that the effect of daily open behaviors on daily cognitive engagement varied as a function of age ($B = -0.07$, $SE = 0.03$, $p < .05$, 95% CI [-0.125, -0.007]). For young-old adults (mean age - 1 SD), the effect of open behaviors on cognitive engagement was stronger ($B = 1.49$) than for old-old adults (mean age + 1 SD; $B = 0.61$). Moreover, the results of the random effects showed that participants significantly differed in their intercepts of daily cognitive engagement.

Pseudo R2. Lastly, we calculated the pseudo R2 by comparing the two models for open behaviors and cognitive engagement (Step 1 and Step 2). The pseudo R2 is an indicator of how much (in percentage) the conditional random-intercept-random-slope model (Step 2) improves upon the unconditional random-intercept-only model (Step 1) by reducing the residual variance of the outcome variable. The conditional random-intercept-random-slope model (Step 2) has led to an improvement compared to the unconditional random-intercept-only model (Step 1) by reducing the residual variance of cognitive engagement by 8.4% (pseudo R2 within-person) and 39.7% (pseudo R2 between-person), respectively.

Table 13. *Multilevel Model for Open Behaviors on Cognitive Engagement*

	Estimate	<i>SE</i>	95% CI
Fixed effects			
Intercept	3.15 ***	0.05	[3.048, 3.257]
Slope	1.03 ***	0.17	[0.699, 1.364]
Person-mean open behaviors	2.35 ***	0.34	[1.679, 3.024]
Age	-0.01	0.01	[-0.021, 0.011]
Education	0.06	0.03	[-0.002, 0.125]
MMSE	-0.07	0.04	[-0.151, 0.015]
Trait openness	0.14 *	0.07	[0.006, 0.264]
Time	-0.01	0.01	[-0.022, 0.002]
Slope × age	-0.07 *	0.03	[-0.125, -0.007]
Slope × education	0.04	0.12	[-0.191, 0.277]
Slope × MMSE	0.04	0.15	[-0.257, 0.334]
Slope × trait openness	0.12	0.23	[-0.338, 0.581]
Random effects			
Intercept	0.24 ***	0.04	[0.166, 0.304]
Slope	0.65	0.40	[-0.139, 1.437]
Residuals	0.36 ***	0.02	[0.329, 0.392]
AIC	2537.80		
BIC	2619.55		

Note. N_1 = 136 participants, N_2 = 1,355 observations. MMSE = Mini Mental State

Examination; *SE* = standard error; 95% CI = 95% confidence intervals; AIC = Akaike

Information Criterion; BIC = Bayesian Information Criterion. Slope represents a latent variable that is defined by the within-person regression of open behaviors on cognitive engagement and may vary across between-person predictors. The random effect estimates were represented by random effect variances. The estimates are unstandardized coefficients.

* $p < .05$., *** $p < .001$.

Neurotic behaviors and cognitive complaints. We also tested the association between neurotic behaviors on cognitive complaints, and controlled for age, education, general cognitive status, trait neuroticism, and time (Table 14). The fixed effect of the slope was 0.35 ($B = 0.35$, $SE = 0.32$, $p = .278$, 95% CI [-0.280, 0.976]), indicating that days of neurotic behaviors were unrelated to cognitive complaints on the same days within individuals. Likewise, daily neurotic behaviors were unrelated to daily cognitive complaints at the between-person level (see person-mean neurotic behaviors in Table 14). Concerning the covariates, age was significantly related to daily cognitive complaints, whereas education, general cognitive status, and time were not. The predicted increase in the intercept of cognitive complaints was 0.02 for a one-unit increase in age ($B = 0.02$, $SE = 0.01$, $p = .023$, 95% CI [0.002, 0.042]). This suggests that for every one-unit increase in age, there is a 0.02 increase in daily cognitive complaints. We did not find any significant cross-level interactions. However, the results of the random effects showed that participants significantly differed in their intercepts of daily cognitive complaints.

Pseudo R^2 . Finally, the pseudo R^2 was calculated for neurotic behaviors and cognitive complaints too. The conditional random-intercept-random-slope model (Step 2) improved upon the unconditional random-intercept-only model (Step 1) by reducing the residual variance of cognitive complaints by 2.8% (pseudo R^2 within-person) and 12.2% (pseudo R^2 between-person), respectively.

Table 14. *Multilevel Model for Neurotic Behaviors on Cognitive Complaints*

	Estimate	SE	95% CI
Fixed effects			
Intercept	1.02 ***	0.07	[0.883, 1.150]
Slope	0.35	0.32	[-0.280, 0.976]
Person-mean neurotic behaviors	1.45	1.20	[-0.895, 3.798]
Age	0.02 *	0.01	[0.002, 0.042]
Education	0.04	0.04	[-0.046, 0.116]
MMSE	-0.09	0.06	[-0.204, 0.015]
Trait neuroticism	0.09	0.06	[-0.032, 0.204]
Time	-0.01	0.01	[-0.024, 0.005]
Slope \times age	-0.05	0.05	[-0.146, 0.052]
Slope \times education	0.04	0.20	[-0.356, 0.435]
Slope \times MMSE	-0.12	0.28	[-0.674, 0.439]
Slope \times trait neuroticism	0.36	0.28	[-0.186, 0.904]
Random effects			
Intercept	1.06 ***	0.07	[0.883, 1.150]
Slope	0.35	0.32	[-0.280, 0.976]
Residuals	0.48 ***	0.02	[0.436, 0.520]
AIC	2899.29		
BIC	2980.94		

Note. N_1 = 136 participants, N_2 = 1216 observations. MMSE = Mini Mental State Examination;

SE = standard error; 95% CI = 95% confidence intervals; AIC = Akaike Information

Criterion; BIC = Bayesian Information Criterion. Slope represents a latent variable that is

defined by the within-person regression of neurotic behaviors on cognitive complaints and

may vary across between-person predictors. The random effect estimates were represented by

random effect variances. The estimates are unstandardized coefficients.

* $p < .05$., *** $p < .001$.

4.4.4 Discussion

The aim of the present study was to investigate the associations between behaviors related to personality and cognition in daily life of healthy older adults. We reported three main findings. First, we revealed a positive relation between open behaviors and cognitive engagement both at the between- and within-person level. Second, the effect of open behaviors on cognitive engagement varied as a function of age. Third, the results showed no associations between neurotic behaviors and cognitive complaints at both levels of analysis. These main findings and possible implications are discussed in more detail below.

In line with our hypotheses, we found a positive association between daily open behaviors and daily cognitive engagement at both levels of analysis. The between-person association suggests that individuals differed from each other in their daily levels of open behaviors and cognitive engagement. Thus, our results support previous between-person findings (e.g., Ackerman & Goff, 1994; Chamorro-Premuzic & Furnham, 2004; Hogan et al., 2012; Soubelet & Salthouse, 2010), and show that these associations also hold within individuals over ten days. The within-person association suggests that on days when participants behaved more openly, they also were more engaged in cognitive activities (e.g., philosophizing about things, focusing on an abstract problem, watching an educational or documentation movie). In contrast, being less open was associated with low cognitive engagement within individuals. Interestingly, age moderated the within-person relationship between open behaviors and cognitive engagement. For young-old adults (< 70 years), the effect of open behaviors on cognitive engagement was stronger than for old-old adults (> 70 years). It seems possible that young-old individuals may face more opportunities to behave openly and to show more cognitive investment in their daily life than older individuals, thus enhancing a stronger within-person association. For instance, they may have a larger social network that increases the probability to talk about things from different perspectives, to listen to a person who shares other values/opinions or to try novel activities. It may also be that old-

old adults have more age-related issues (e.g., lower MMSE scores) compared to younger-old adults, which could limit the adoption of open-related behaviors (e.g., talk about things from different perspectives).

In contrast to our expectations, individuals who reported more neurotic behaviors did not complain more about their cognition at the daily between-person level. This finding is contrary to previous laboratory-based between-person studies showing that neurotic individuals may negatively color their cognition (Mascherek et al., 2011) and/or focus on cognitive problems (Ponds & Jolles, 1996). This could be good news for neurotic people in the sense that they are not more prone to experiencing cognitive complaints in daily life. The inconsistency between previous and our results may be due to the different context in which neuroticism and neurotic behaviors were assessed. Indeed, phenomena demonstrated in the laboratory may not actually occur in the real world (Bolger & Laurenceau, 2013). A possible explanation for this disconnection may be the retrospective and generalized responses in self-reports conducted in the laboratory. These self-reports may be biased by memory processes and cognitive heuristics, and they leave open the possibility that people respond on the basis of what they consider typical (Schwarz, 2012). As such, individuals refer to their typical cognitive failure when they rate their general cognitive complaints in the laboratory, and they thus may overestimate them compared to if their actual behaviors are assessed on a daily basis. Furthermore, it seems possible that associations between neurotic behaviors and cognitive complaints are only evident in individuals who suffer from mild cognitive impairment or dementia or who are highly neurotic. Put differently, it can be assumed that as long as neurotic individuals are healthy and report some minor daily cognitive hassles only, there seems to be no significant link, but it might be different for individuals who suffer from serious cognitive problems or who are highly neurotic. This may also be a possible explanation for the lack of significance at the within-person level. On days when older adults reported more neurotic behaviors, they did not systematically report more cognitive

complaints on these days. As such, negative aspects of neurotic behaviors on a specific day do not seem to negatively color a healthy person's cognition and lead to cognitive complaints on that day. Future studies that consider group comparisons (healthy and cognitively impaired individuals) are necessary to support this assumption. There may also be different mechanisms underlying these linkages at each level of analysis. This is an important issue for future research too.

The present findings may have important implications. In terms of between-person implications, people varied from one another in their daily levels of open behaviors and cognitive engagement. Some people reported higher levels than others, whether due to internal or external circumstances. These individual differences are important for professionals involved in the providing of personality or cognitive interventions to older adults. This means, not everyone who participates in an intervention is equivalent, and an intervention that works for one individual may not work for another. With respect to within-person implications, our results suggest that individuals have the flexibility and opportunity to act in different ways (i.e., behave more or less openly) that in turn may bring about personally desired consequences (i.e., higher cognitive engagement) (cf. Fleeson, Malanos, & Achille, 2002). At a general level, this is in line with the "doing" view of personality (Cantor, 1990). In other words, daily cognitive engagement is conditional on what individuals are doing (i.e., open behaviors). Therefore, individuals are able to influence desired outcomes through their behaviors. In that sense, it is possible that a simple intervention with the goal to encourage individuals to act more openly may be successful to increase their cognitive engagement (and vice versa). In turn, cognitive engagement may positively influence cognitive functioning in older age (e.g., Wilson et al., 2002; Wilson, Segawa, Boyle, & Bennett, 2012). As such, open behaviors may reflect a pathway by which cognitive engagement bestows an advantage in cognitive functioning in later life (Sharp, Reynolds, Pedersen, & Gatz, 2010; Soubelet & Salthouse, 2010). Before it can be established as useful, the causality of these relationships,

the possible mediating role of cognitive engagement, and its applicability to personality and cognitive interventions need to be established. But the first and critical step, showing that these processes with regard to open behaviors and cognitive engagement do occur within older adults, has now been taken.

It should be noted that this finding is relevant not only to those who have a need to increase their cognitive engagement (e.g., individuals who realize that their cognitive abilities decline and want to “fight against it” or in individuals who want to improve their cognitive performance), but also to cognition-personality research. Why? If between-person associations also hold at the within-person level, useful opportunities may be provided. First, variation in daily behaviors is more rapid to observe than change in traits (cf. Fleeson et al., 2002), because an ambulatory assessment study (to investigate variation in daily behaviors) can be conducted over several days or weeks, whereas a longitudinal study (to investigate change in traits) needs to be conducted over several months, years or decades. Hence, cognition-personality research may gain knowledge (or at least suggestions for future research) more rapidly if isomorphism is confirmed. Second, methods of experimental control could be applied at the within-person level. To the extent that behaviors have the same properties as traits, researchers should be able to randomly assign individuals to behaviors and instruct them to behave in those ways (Fleeson et al., 2002). Thus, cognition-personality research may gain valuable information for possible intervention strategies by applying experimental manipulation of behaviors.

Limitations and Future Directions

The present study makes three noteworthy contributions. First, a real-life research design was applied to assess the within-person associations between open behaviors and cognitive engagement as well as neurotic behaviors and cognitive complaints. Second, behaviors were captured in daily life rather than artificially forming groups of individuals (e.g., high and low neuroticism) that may not adequately represent how individuals behave in

their everyday life. In addition, we identify some opportunities for future research. Third, the ecological validity of the ambulatory assessment method was a strength of the study.

Participants responded to self-report questions at the end of each day in the present study.

This was a first attempt to examine the associations of interest at the daily within-person level. Furthermore, it is not known what time interval would be the best to capture the variation of behaviors related to personality and cognition. Nevertheless, further research may assess these behaviors more often per day to receive a fine-grained picture of how these associations unfold in daily life.

Additionally, it seems worthwhile to extend the present time-triggered approach and employ event-triggered assessments where participants are instructed to respond, for example, each time they performed an open behavior such as enjoying music. Importantly, the present study was correlational and descriptive in nature, and causality was not established. In our multilevel models, we looked only in one direction, that is from personality-related behaviors toward cognitive behaviors. However, the direction of influence cannot be addressed with the current data. It is also possible that cognitive behaviors influence personality-related behaviors. Future studies that either manipulate frequency of personality-related behaviors or intervene on cognitive variables are necessary to disentangle the bidirectional relationship and to reveal causal directionality. Our results inform on possible intervention strategies: For example, encouraging individuals to act more openly may be successful to increase their cognitive engagement.

Conclusion

To conclude, the present study significantly contributes to the research field of personality-cognition interrelations by providing support for positive associations between open behaviors and cognitive engagement both at the between- and within-person level. However, neurotic behaviors and cognitive complaints were unrelated at both levels of analysis. These findings suggest that conclusions drawn from laboratory research may not

necessarily hold in daily life. Further work is needed to better understand how, when, and why these behaviors are linked (or not) in daily life.

4.5 Study 5: Using Eye Tracking to Assess Personality Manifestations in Daily Life?¹⁷

4.5.1 Introduction

Moving the eyes is one of the key ways through which humans gather information about the world around them. Consequently, eye tracking has become an important method to investigate eye movements in different areas of psychology such as cognitive, neuropsychological, developmental and personality science (e.g., Duchowski, 2002; Rayner, 1998, 2009). Across all these research areas, it has been of interest to identify factors that shed light on different eye movement patterns. Generally, visual exploration is driven by two main factors, that is the stimuli of the environment as well as personal interests and intentions (Treue, 2003). One factor that belongs to the latter category and has received relatively little attention is personality (Risko, Anderson, Lanthier, & Kingstone, 2012). Specifically, what is the role of individual differences in personality for eye movements? For example, do individuals who are more open to experience look at more different things when they inspect their surroundings? Do individuals who are high on extraversion look more often at other people?

Traditional Laboratory-Based Eye Tracking Studies

Previous research showed significant associations between different personality traits and eye movements of young adults in the laboratory. For instance, it has been suggested that individual differences in personality such as anxiety (Paulitzki, Risko, Oakman, & Stolz, 2008) or loneliness (Wilkowski, Robinson, & Friesen, 2009) influence various forms of attention (e.g., task switching or gaze-triggered orienting). With regard to the Big Five personality traits, participants with higher levels of openness showed increased durations of fixations to the eyes of an individual who sat opposite the participants (Matsumoto, Shibata,

¹⁷A similar version of this study has been submitted to *Social Psychological and Personality Science*. This chapter may not exactly replicate the original version. It is not the copy of record. Original article: Aschwanden, D., Langer, N., & Allemand, M. (submitted). *Using eye tracking to assess personality manifestations in the wild? Piloting a real-life assessment paradigm*.

Seiji, Mori, & Shioe, 2010). According to the authors, a possible explanation may be that individuals who show higher levels of openness attempt to obtain information from the other person. In a car advertisement study, neuroticism was positively related to the duration and number of fixations on cars, but negatively related to the duration and number of fixations on price and text (Nitzschner, Nagler, Rauthmann, Steger, & Furtner, 2015). Rauthmann, Seubert, Sachse, and Furtner (2012) suggested that individuals with high levels of neuroticism might take longer in processing complex stimuli because they try to validate their value to prevent themselves from potential harm (e.g. doubtful cars). Furthermore, curiosity has been revealed as a robust and reliable predictor of an individual's eye movement behavior in laboratory scene-viewing of buildings, interiors, and landscapes (Risko, Anderson, Lanthier, & Kingstone, 2012). This means, participants with higher levels of curiosity showed higher levels of exploratory behaviors (i.e., higher number of regions visited) in the scene-viewing task. In general, the effect sizes of the results reported in literature range from small to medium (cf. Rauthmann et al., 2012).

Eye Tracking Studies in the Wild

A search of the literature revealed few studies that investigated the associations between personality traits and eye movements in the wild or in real life, respectively. Hoppe, Loetscher, Morey, and Bulling (2015) examined whether curiosity could be predicted based on natural eye movements during a real-world task. It should be noted that curiosity was examined as the outcome here, whereas curiosity was used as the predictor in the study of Risko et al. (2012). Hoppe et al.'s participants ($N = 26$) were given \$5 to go to one of the shops on campus and buy an item of their choice which they were allowed to keep or eat while wearing a mobile eye tracker. After 10 to 15 minutes, the participants returned to the laboratory and filled in two curiosity questionnaires. For 11 of 26 participants, Hoppe and colleagues (2015) predicted the correct class of curiosity out of up to four classes (depending on the curiosity scale as they used more than one scale to assess curiosity). Apart from Hoppe

et al. (2015), there is a general lack of research of the associations between personality traits and natural eye movements in real life. Moreover, all aforementioned studies relied on (undergraduate) student samples. But investigating these associations in daily life of older adults is important, because it helps to better understand how older people are and how they gaze, and how these associations are manifested in daily life and not only in the laboratory (cf. Allemand & Mehl, 2017; Wrzus, & Mehl, 2015). Furthermore, using eye tracking in personality research expands the traditional methods repertoire of self-reports and behavioral observations (cf. Aschwanden, Allemand, & Hill, in press). It seems particularly worthwhile to use eye tracking as an objective method in aging research, because older age is a phase that is particularly susceptible to individual and environmental changes and non-normative events (Baltes, Lindenberger, & Staudinger, 2007). If multiple measurement occasions are sampled, it may be that older individuals tend to change their internal standards of perceptions due to the accompanying changes that aging brings with it, and this may impair the interpretation of study results (Möttus, Johnson, & Deary, 2012a). Although research may establish measurement invariance to consider this issue, objective methods such as eye tracking may be an interesting and innovative alternative.

Innovation: Testing a Real-Life Assessment Paradigm

Before researchers can start to investigate the associations between personality traits and eye movements in real life, it is required to test and establish an appropriate real-life assessment paradigm. Inspired by the study of Hoppe and colleagues (2015), we undertook a feasibility study to pilot grocery shopping as a real-life assessment paradigm with older adults. We focused on grocery shopping because it is a typical situation in daily life of older adults. Establishing such a real-life assessment paradigm is important for at least three reasons: (1) its ecological validity, (2) because it includes an objective measurement method, and (3) the task is familiar to older participants. As this feasibility study introduces a simple, but innovative real-life assessment paradigm with older adults, it must address three key

feasibility issues. First, will older adults wear the eye tracker the whole time during grocery shopping? Our real-life assessment paradigm required that participants do not remove the eye tracker in order to record data. Second, is it possible to successfully record eye movements of older adults in a grocery store? There are several factors that might influence the recording of eye movements in an unstandardized setting, for example the illumination, participants' free movements, and the varying distance to the shelves. Third, is it possible to evaluate the eye movements with respect to three areas of interest? Unlike laboratory-based eye tracking studies, this feasibility study did not use markers that facilitate the eye tracker data analysis. In contrast, all videos of the scene camera had to be coded manually by two coders.

In addition, we explored whether there are associations between different personality traits and eye movements (i.e., number of fixations on three areas of interest) during grocery shopping. For instance, we were interested whether individuals high on openness gaze at more different products during grocery shopping. However, we did not form specific hypotheses, but rather explore the research topic to form the basis for more conclusive research. It is important to note that these exploratory analyses provide preliminary results, because the sample size of this feasibility study greatly limits the power to detect links between personality traits and eye movements. In particular, our focus was on piloting the real-life assessment paradigm as this is one of the first attempts to assess eye movements in real life.

4.5.2 Methods

Participants

Participants came from the feasibility study "Big Five Shopping Eye Tracker Study" (B5-SES). A total of 38 healthy older individuals (79% female) were recruited via an advertisement in a magazine for older adults as well as a database of older adults who are interested in study participations. Participants met the following inclusion criteria: fluent German or Swiss German speaker, full mobility, normal or corrected-to-normal vision, and no psychiatric or neurologic diseases. The mean age of the sample was 72.85 years ($SD = 7.25$,

range = 59-87 years). The mean level of education was 5.89 on a scale from 1 = *no education* to 7 = *university*. All participants had a Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) score higher than 26, and thus did not show signs of cognitive impairment (MMSE scores < 24).

All methods and procedures were approved by the ethics committee for psychological and related research of the University of Zurich. The participants gave their written informed consent prior to study participation.

Procedure

Participants came to the laboratory and completed several questionnaires (e.g., sociodemographic, health, personality) and cognitive tasks (e.g., MMSE). Next, they walked to a local supermarket (Coop¹⁸ Center Eleven in Zurich-Oerlikon) accompanied by a student assistant. In the supermarket, the eye tracker was calibrated and participants were given 30 Swiss Francs (approximately \$30) to do their grocery shopping. Participants were allowed to buy food and non-alcoholic drinks. While participants did their grocery shopping, a student assistant waited in the entrance hall of the supermarket, monitoring the laptop to which the eye tracker data was sent in real-time. After the shopping, they were asked whether they behaved typically or not during grocery shopping, and whether they have ever been in this supermarket before their study participation. Furthermore, the receipts were collected by the student assistant to know what participants bought. Participants were allowed to keep the items they bought. On average, participants shopped for 10.55 minutes ($SD = 4.34$, range = 4-21 minutes). The shopping duration was unrelated to personality traits ($r_s = -.34$ to $.23$).

Measures

Personality traits. The Big Five personality traits (openness, neuroticism, conscientiousness, extraversion, and agreeableness) were measured using the Big Five Inventory (John, Naumann, & Soto, 2008). The 45 items were rated on a 7-point Likert scale

¹⁸Coop is one of Switzerland's largest retail and wholesale companies.

ranging from 0 (*strongly disagree*) to 6 (*strongly agree*). Moreover, the personality trait curiosity was assessed using the Curiosity and Exploration Inventory (CEI-II; Kashdan et al., 2009). This survey consists of two subscales, that is exploration (four items) and absorption (three items). Exploration reflects an orientation toward seeking novel and challenging objects, events, and ideas. Absorption reflects the ability to self-regulate attention to allow for immersion in activities. The total of seven items were rated on a 4-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). The internal consistencies (Cronbach's alpha) of all personality measures ranged from acceptable ($\alpha = .71$; curiosity) to good ($\alpha = .88$; extraversion).

Eye tracking. The wireless *Dikablis Professional Eye Tracking Glasses* and the corresponding software D-Lab Version 3.0 from Ergoneers (<http://www.ergoneers.com/en>) were used to assess eye movements. Binocular gaze data was recorded at 60 Hz, and the scene video camera recorded on full high definition (HD) resolution (1920 x 1080 pixel). The accuracy for pupil detection was $0,05^\circ$, and $0,1^\circ$ - $0,3^\circ$ for glance direction. A wide-angle lens was put on the scene camera which allowed more of the scene to be included in the video. The eye tracker glasses were connected to a tablet that was stored in a small backpack carried by the participants (see Figure 3). Data was stored on this tablet and sent via WLAN to a laptop in real-time. WLAN was provided by a router. The eye tracker was calibrated before participants did their grocery shopping. We analyzed the number of fixations on different areas of interest, because a meta-analysis has shown that this eye movement parameter is one of the most widely used parameter (Jacob & Karn, 2003). Fixations are defined as pauses over informative areas of interest (cf. Salvucci & Goldberg, 2000). Using D-Lab 3.0 (Ergoneers, 2014), the fixations were calculated according to the principle of Salvucci and Goldberg (2000).

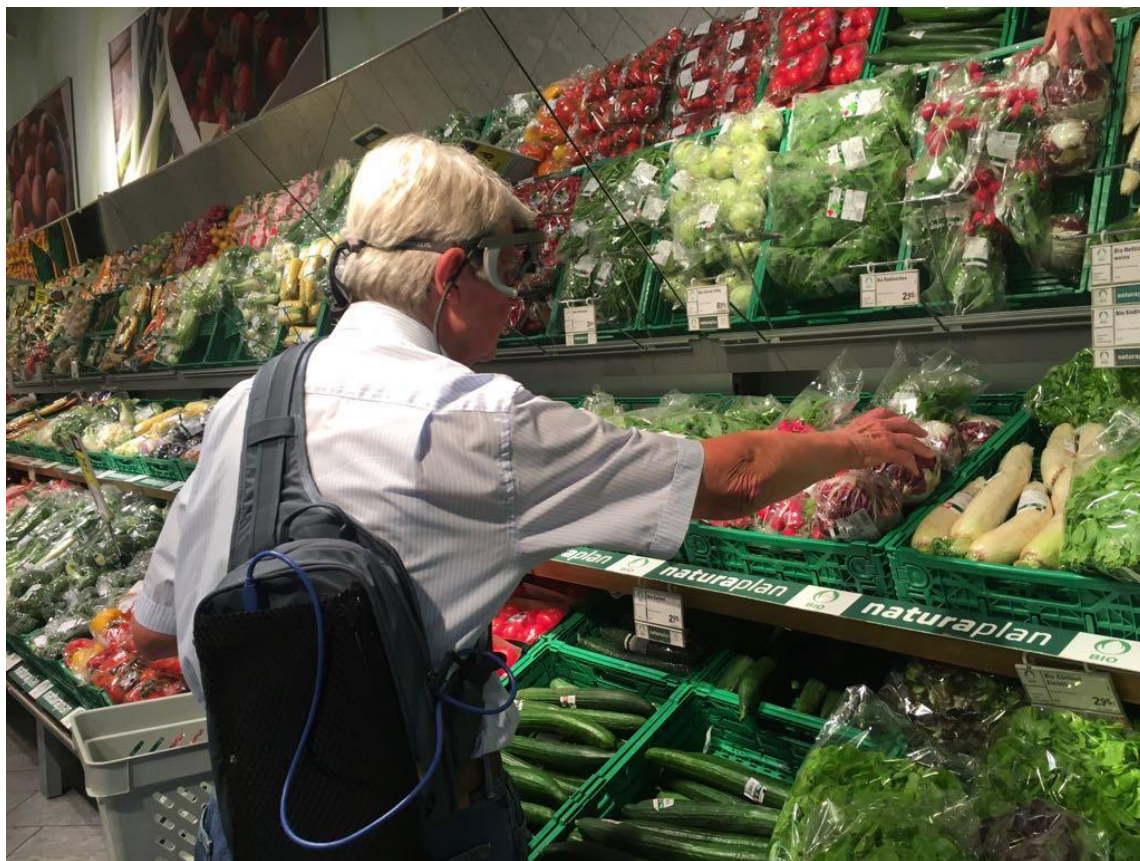


Figure 3. *Testing Grocery Shopping as a Real-Life Assessment Paradigm*

Notes. The eye tracker glasses were connected to a tablet that was stored in a small backpack carried by the participants. This participant kindly agreed to include this picture in scientific presentations and publications.

Coding of the Video Material

The centerpiece of the present feasibility study was on coding the video material. The videos from the scene camera could not be coded automatically because the eye tracker data were collected in the wild (i.e., real-life context), having no standardized conditions and thus disclaiming to use markers that usually facilitate the eye tracker data analysis. Hence, the most time-consuming part of the feasibility study was to code the scene videos. All videos were watched and coded in slow motion by two coders. The coders completed several training sessions before coding the video material of this feasibility study. The videos were coded using the eye tracker software D-Lab 3.0 provided by Ergoneers. First, three areas of interest were defined, that is (a) different products (i.e., all products in the supermarket), (b) price tags, and (c) the products that were actually bought (i.e., products that participants put in their shopping basket and paid based on the receipts). Second, heatmaps were used to visualize fixations lasting 100ms or longer (Rauthmann et al., 2012). The heatmaps were shown time based (100ms), so they did not overlay for fixation visualization. The spot radius (size of heatmap) was set to 35 pixels. Third, two coders counted the number of fixations (shown as red dots) for each area of interest separately.

Statistical Analyses

Eye tracker measure. After the videos were coded, the number of fixations on different area of interest were corrected for the individual shopping duration and the individual total number of fixations during grocery shopping. As described before, participants differed in their shopping duration. Furthermore, it seems possible that some participants looked at one of the three areas of interest all the time during grocery shopping, whereas others might have looked at the areas of interest less frequently in relation to their total number of fixations during grocery shopping. Hence, we calculated the mean of number of fixations on the areas of interest per minute, divided it by the total number of fixations per minute, and used this measure for the analyses. To calculate the mean of number of fixations

on the areas of interest per minute, the number of fixations on the areas of interest was divided by the total number of fixations and by the shopping duration in minutes. To compute the total number of fixations per minute, the total number of fixations was divided by the shopping duration in minutes.

Power. Of the 38 participants, $n = 10$ (26.3%) were excluded from exploratory data analyses (i.e., correlations) due to missing eye tracker data (note that the reasons for missing eye tracker data are further described in the section “feasibility” of the results). Referring to prior work, the correlation coefficients of the associations between personality traits and eye movements range from $r = .05 - .30$ in laboratory-based studies (Rauthmann et al., 2012). The present sample provides power¹⁹ of 6% to estimate a correlation coefficient of .05 at the 5% significance level, and a sample size of 3136 participants would be needed to achieve 80% power for this value. If true correlation coefficients are .30, the power estimate would be 35%. A sample size of 84 participants would be needed to achieve 80% power for this value. Based on the given sample size, it is possible to detect effects that are $>.50$ ($N = 28$, significance level = 0.05, power = 80%). The present feasibility study seems underpowered to investigate the rather weak associations between personality traits and eye movements, but we included them for exploratory purposes. However, these results should be interpreted with caution.

Correlations. Spearman correlations (nonparametric data) were performed to examine the associations between personality traits and the number of fixations. These exploratory data analyses are based on $n = 28$ (75% female). The analyses did not include covariates because the present study piloted the feasibility of grocery shopping as a real-life assessment paradigm. In addition to p -values, we provide 95% confidence intervals (CIs) when reporting the correlation coefficients. CIs contain information about the size of an effect and its precision, thus being more informative than p -values alone (Cohen, 1994). The CIs were based on bias-corrected bootstrapping (1,000 bootstrap samples).

¹⁹Power calculations were conducted using the “pwr” package (Champely, 2017) in R version 1.1.383 (R Core Team, 2016).

4.5.3 Results

Feasibility. To determine if it realistic to use our real-life assessment paradigm with older adults, we examined three key feasibility issues. First, 37 participants wore the eye tracker the whole time during grocery shopping. One participant decided against wearing the eye tracker during grocery shopping. This participant wore the eye tracker during the calibration process, but then felt too odd to wear it for the real-life assessment paradigm. Thus, 37 out of 38 participants completed the real-life assessment paradigm (attrition rate: 2.6%). Second, it was possible to successfully record eye movements in a grocery store for 28 of 37 participants (75.7%). The reasons for missing eye tracker data were technical problems such as the scene camera was not recording (55.6%), the scene video was frozen (33.3%), or the connection cable from the eye tracker glasses to the tablet was displayed (11.1%). Third, it was possible to evaluate the eye movements with respect to three areas of interest for 28 of 28 videos (100%). The inter-rater reliability Krippendorff's Alpha (Hayes & Krippendorff, 2007) was acceptable ($>.60$) for all areas of interest (number of fixations on different products = .77; number of fixations on price tags = .61; and number of fixations on products bought = .71). It should be noted that the video coding was very time-intensive because no markers were used (>24 hours to code a video of 10 minutes).

Preliminary Correlations. Table 15 shows the means, standard deviations, and ranges for all personality traits and the coded eye movements. Table 16 displays the Spearman's correlations coefficients and the bias-corrected bootstrap confidence intervals for the associations of interest. With respect to the number of fixations on different products, no significant correlations were found. For the number of fixations on price tags, no relation to the Big Five and curiosity was found either. Furthermore, we did not find any significant associations for the number of fixations on products bought.

Table 15. *Descriptive Statistics*

Personality traits	<i>M</i>	<i>SD</i>	Range
Openness	4.17	0.81	0-6
Neuroticism	2.14	1.09	0-6
Conscientiousness	4.75	0.86	0-6
Extraversion	4.03	1.16	0-6
Agreeableness	4.28	0.77	0-6
Curiosity	3.10	0.47	1-4
Exploration	3.23	0.54	1-4
Absorption	2.92	0.59	1-4
Fixations			
Different products	333.14	182.41	89-752
Price tags	61.29	39.21	6-138
Bought products	49.79	34.10	6-151
Fixations controlled for shopping duration and total fixations			
Different products	0.07	0.05	0.0-0.2
Price tags	0.01	0.01	0.0-0.01
Bought products	0.01	0.02	0.0-0.01

Note. $N = 28$. Means (*M*), standard deviations (*SD*) and possible ranges of the variables

of interest are shown in raw scores. The range of eye movements refers to the actual range.

Table 16. *Correlations between Personality Traits and Eye Movements*

	Openness	Neuroticism	Conscientiousness	Extraversion	Agreeableness	Curiosity	Exploration	Absorption
Different products	-.04 [-.398, .438]	.27 [-.114, .594]	-.15 [-.503, .244]	-.25 [-.573, .113]	.10 [-.436, .283]	-.05 [-.462, .328]	.18 [-.254, .539]	-.11 [-.489, .294]
Price tags	-.05 [-.493, .384]	.20 [-.195, .549]	-.24 [-.579, .202]	-.34 [-.616, .009]	.29 [-.575, .067]	-.02 [-.446, .434]	.14 [-.316, .597]	-.04 [-.481, .425]
Bought products	.10 [-.309, .532]	.02 [-.379, .356]	.12 [-.245, .452]	-.13 [-.481, .270]	.16 [-.276, .535]	.03 [-.375, .444]	.23 [-.190, .607]	-.01 [-.426, .430]

Note. $N = 28$. Table shows Spearman's correlation coefficients. BCa bootstrap 95% CIs are reported in brackets.

Proportions. In addition, we analyzed the proportions of the number of fixations on the three different areas of interest (proportion 1: different products / price tags, proportion 2: different products / bought products, proportion 3: price tags / bought products) to descriptively compare them. On average, participants looked 7.58 times more at different products in relation to price tags (*SD*: 7.98). They also looked 9.53 times more at different products in relation to the products they actually bought (*SD*: 7.65). However, the proportion between price tags and bought products was rather small, participants looked 1.67 times more at price tags than at bought products (*SD*: 1.85). Subsequently, we tested whether the personality traits were associated with these proportions. Only one significant Spearman correlation was found, that is agreeableness was negatively related to proportion 3 (price tags / bought products), $r_s = -.41$, 95% CI [-.691, -.025], $p < .05$. This means, higher levels of agreeableness were related to a lower proportion 3 or lower levels of agreeableness were related to a higher proportion 3.

4.5.4 Discussion

The present feasibility study aimed to assess eye movements using a real-life assessment paradigm. Furthermore, we explored possible associations between different personality traits and these eye movements. We successfully piloted grocery shopping as a real-life assessment paradigm with older adults. The current assessment paradigm was feasible for 97.4% of participants. Furthermore, it was possible to record eye movements for 75.7% of participants, and 100% of the videos could be coded. Thus, there is preliminary support for the use of grocery shopping as a real-life assessment paradigm with older adults. We did, however, encounter some challenges with respect to the data collection in the supermarket and the video coding. For example, the connection cable from the eye tracker glasses to the tablet had to be tapped down, otherwise the participants' movements could have displayed the cable and thus interrupted the recording. Furthermore, sometimes it was difficult to recognize specific products during the video coding process because of the

changing illumination in the supermarket. This feasibility study was almost unique among eye tracker studies in that we ran it in the wild and involved older adults rather than undergraduate students. Hence, some helpful practical recommendations might be derived from our feasibility study (see Appendix). These recommendations may be useful for future studies that plan to innovatively expand the traditional methods repertoire of personality science by using eye tracking in a real-life setting.

In the present feasibility study, no associations between personality traits and the number of fixations on three areas of interest were found. However, with our small sample size, caution must be applied because our feasibility study seems underpowered to detect these associations (although it should be noted that the sample size of Hoppe et al. (2015) was $N = 26$). Our focus was on the feasibility of the real-life assessment paradigm. Now, as this first and critical step has been taken, there is abundant room for further research. Future studies including larger samples and possible covariates are needed to determine whether there are no associations or under which circumstances different personality traits and eye movements are related in real life. Moreover, one potential line of future research might be to develop an automated coding method to accelerate the eye tracker data evaluation.

To conclude, using eye tracking to assess personality manifestations in real life might yield some challenges such as a very time-intensive video coding process, however, it may also open up new avenues for personality research. The present feasibility study emphasizes that grocery shopping as a real-life assessment paradigm is suitable for older adults. Furthermore, it provides important insights into the eye tracker data collection in real life, and may have formed some basis for future research.

5. General Discussion

The main goal of the current work was to examine the long-term development and daily short-term dynamic processes of cognition-personality relations in healthy older adults. More specifically, the present work was motivated by five research questions regarding (1) differences in cognitive development due to education, (2) cross-lagged cognition-personality relations, (3) cognitive complaints as a mediator between cognition and emotional stability, (4) daily behaviors related to cognition and personality, and (5) personality and eye movements in real life.

In this last section, the empirical studies are briefly summarized. Previous to each summary, the research questions are raised as a reminder. A short discussion about the effect sizes of the evidenced associations follows (see section 5.2). Because the present thesis brought together two domains that are often investigated separately, the integration of cognitive and personality research is discussed. Specifically, the use of cognitive methods in personality research is deliberated (see section 5.3). Furthermore, future directions including possible intervention strategies arising from this thesis are presented (see section 5.4). The thesis closes with some final remarks about the current work (see section 5.5). In general, the emphasis of this last section is on suggestions for further research because the results of each study were discussed in detail in the corresponding sections of the preceding chapters.

5.1 Summary of the Empirical Studies

Research Question 1: What is the role of education in cognitive aging? Are there differences of cognitive development across five years between highly and averagely educated individuals? The purpose of Study 1 was to examine the role of very high education (professors) on cognitive development in older age. Previous studies have demonstrated that cognitive abilities such as visual and verbal memory, naming, verbal fluency as well as fluid intelligence tend to decline in older age. However, education seems to be a promising non-biological factor for maintaining cognition in late life. Only few studies have investigated the

relationship between education and cognitive abilities in older age and almost none of them tested the effect of high education on cognitive development. Two samples of older adults with either average education ($n = 236$, $M_{\text{age}} = 72.67$ years, $M_{\text{education}} = 13.11$ years) or high education ($n = 39$, $M_{\text{age}} = 72.87$ years, $M_{\text{education}} = 20.78$ years) were tested accordingly to their cognitive performance across five years. The cognitive tests measured episodic memory, working memory and perceptual speed. Although the highly educated sample outranked the averagely educated sample in tests of working memory (at both measurement occasions) and perceptual speed (at the second measurement occasion), no effect of education on cognitive development across five years was found. This may be due to a lack of variability in the performance of both groups over time. Moreover, additional analyses indicated that cognitive engagement may be more relevant for perceptual speed than education. To be more specific, averagely educated individuals who reported high levels of cognitive engagement did not show lower perceptual speed than highly educated individuals. In sum, the findings of Study 1 suggest that although highly educated individuals outperform their less educated peers in certain cognitive tests, it cannot be shown that education has a beneficial effect on cognitive development in older age.

Research Question 2: How are levels of different cognitive abilities related to levels of different personality traits four years later? Study 2 ($N = 236$) examined stability and change of six cognitive abilities and three personality traits in older age ($M = 74.12$ years) over four years. Furthermore, Study 2 investigated whether levels of one domain were related to the other domain (and vice versa) four years later. The results showed a mean-level decline for processing speed and a mean-level increase for neuroticism. Cross-lagged effects indicated that reasoning at the first measurement occasion was related to openness at the second measurement occasion, and conscientiousness at the first measurement occasion was related to verbal knowledge at the second measurement occasion. In general, few and weak cross-lagged associations between the two domains were found. Study 2 contributes to the research

field by (1) considering cognitive abilities as predictors of personality traits in terms of cross-lagged effects, and (2) differentiating between six cognitive abilities.

Research Question 3: What is the role of cognitive complaints in the longitudinal association between cognition and emotional stability? The existing literature supports a positive relationship between cognition and emotional stability, although findings regarding healthy older adults are inconsistent. Additionally, little is known about the mechanisms that underlie this association. Thus, Study 3 investigated the mediating effect of cognitive complaints on the bidirectional longitudinal association between cognition and emotional stability in older age. The study sample consisted of 500 older individuals ($M_{age} = 62.97$ years) from the Interdisciplinary Longitudinal Study on Adult Development. The results showed that cognitive complaints mediated the effect of cognition on emotional stability over 12 years even when taking baseline emotional stability, baseline cognitive complaints, depressive affect, gender, sensory functioning, objective and subjective health into account. However, cognitive complaints did not mediate the effect of emotional stability on cognition. The results of Study 3 emphasize the importance of investigating cognition as a predictor of personality traits, and indicate that cognitive resources may serve as a protective factor for emotional stability in older age.

Research Question 4: (A) How is cognitive engagement related to open behaviors at the daily between- and within-person level? (B) How are cognitive complaints related to neurotic behaviors at the daily between- and within-person level? Previous studies have established a consistent positive relationship between openness and cognitive engagement as well as between neuroticism and cognitive complaints at the between-person level. However, less is known about these associations at the within-person level in daily life. Using daily assessments, Study 4 examined these associations both at the between-person and within-person level. Understanding the within-person associations is important because this might provide valuable information for simple preventive and interceptive intervention strategies.

Study 4 sampled 136 healthy older participants ($M_{age} = 70.45$ years) from the RHYTHM (Realizing Healthy Years Through Health Maintenance) study. Open and neurotic behaviors as well as cognitive engagement and complaints were measured every evening over ten consecutive days. Multilevel analyses confirmed the hypothesized positive association between daily open behaviors and daily cognitive engagement at the between-person and within-person level. For daily neurotic behaviors and daily cognitive complaints, no associations were found neither at the between-person level nor at the within-person level. These findings extend previous research by providing the investigation of the associations between specific naturally occurring behaviors related to personality and cognition in daily life of older adults at the within-person level.

Research Question 5: (A) Is it possible to successfully record and evaluate eye movements of older adults during grocery shopping? (B) If so, are there associations between different personality traits and eye movements? Previous research showed associations between personality traits and eye movements of young adults in the laboratory. However, less is known about these associations in real life and in older age. Primarily, there seems to be no paradigm to assess eye movements of older adults in real life. The present feasibility study thus aimed to test grocery shopping as a real-life assessment paradigm with older adults. Furthermore, possible links between personality traits and eye movements were explored. The sample consisted of 38 older individuals ($M = 72.85$ years). Participants did their grocery shopping in a supermarket while wearing an eye tracker. The real-life assessment paradigm of Study 5 appears to be feasible to implement and acceptable to older adults. The present feasibility study provides specific practical recommendations which may be useful for future studies that plan to innovatively expand the traditional methods repertoire of personality science by using eye tracking in real life.

5.1.1 Overall Summary

Taken together, the findings of the present thesis contribute to the research field by providing insights into the role of education and personality traits in cognitive aging. Study 1 suggested that education has not been shown to protect against cognitive aging, but cognitive engagement may be a supportive factor of cognitive performance, at least in the domain of perceptual speed. Studies 2-4 evidenced various cognition-personality relations over years (long-term development) and over days (short-term dynamic processes). Finally, Study 5 (feasibility study) showed that the real-life assessment paradigm of grocery shopping was feasible for older adults and may have the potential to explore interindividual differences in personality in daily life.

The section that follows moves on to consider the strength of the associations that the present thesis revealed. The reader may have noticed that the associations between cognition and personality tend to be rather weak. It seems noteworthy to discuss possible reasons for these small effect sizes and to embed them in psychology and other research fields concerned with human functioning.

5.2 The Size of the Effects: A Matter of Linking Maximal Performance and Typical Behavior?

The effect sizes of the evidenced cognition-personality associations in all empirical studies were small (on average approximately .10). This is not surprising, because the associations between cognition and personality seem to be rather weak in general as stated in previous literature (cf. Curtis et al., 2015). Indeed, the correlation coefficients reported in literature indicate a wide range, but on average, they are rather small. As discussed in Study 2 (see section 4.2.4), a possible explanation for these rather weak associations may be that cognition and personality are assessed on different scales. That is, individuals show what they are able to perform (maximal performance) while solving cognitive tasks, and they describe their behaviors and attitudes (typical behaviors) while completing a personality questionnaire.

It is thus reasonable to scrutinize whether or under which circumstances maximal performance is linked to typical behaviors. As such, future research might pay more attention to this distinction between maximal and typical cognitive processes and personality-related experiences and behaviors (see section 4.2.4 for an idea of a future study design).

Another major issue may be the variety of cognitive domains and personality traits. For example, processing speed may be related to neuroticism, while verbal fluency may be related to extraversion, while reasoning may be related to openness and so on. Likewise, the different methodologies used to assess the two domains, different age groups with respect to older age, and the inclusion of different covariates, mediators and moderators may also influence the strength of the link between cognition and personality. In addition, examining long-term development across years may not facilitate these investigations because it is not expected that rather small effects become larger with time, in contrast, it may be even more difficult to examine small effects over a longer time interval.

To better interpret the significance of the relations between cognition and personality, a comparison with the effect sizes found in psychological research is provided. Namely, Meyer and colleagues (2001) tabled the effect sizes for a wide variety of psychological investigations and made several important points. First, for psychology, the modal effect size as a whole is between .10 and .40 on a correlational scale. It appears that the effect sizes for most phenomena in psychology are rather small and not just those in the realm of cognition-personality research. Second, the largest effects for any variables in psychology are in the .50 to .60 range (e.g., the effect of increasing age on declining speed of information processing in adults), and these are quite rare. Third, effect sizes for assessment measures and therapeutic interventions in psychology are similar to those found in medicine (e.g., aspirin to treat heart disease or using chemotherapy to treat breast cancer translate into correlations of .02 or .03). Taken together, the data presented by Meyer and colleagues (2001) make clear that the standards for effect sizes of cognition-personality relations need to be established in light of

what is typical for psychology. Moreover, not only large, but also small effects can have significant consequences for individuals (e.g., Ozer & Benet-Martínez, 2006). For example, lower cognition may shape neuroticism in older age which in turn may negatively influence other life outcomes such as well-being. Therefore, small effects of cognition-personality relationships merit the attention to be further investigated.

5.3 Integrating Cognitive and Personality Research: The Use of Cognitive Methods in Personality Research²⁰

The present thesis brought together two domains that are often investigated separately in their own research fields of cognitive and personality psychology. In doing so, this thesis studied individual differences of personality in cognitive aging (Studies 2-4). Moreover, eye tracking, a method that is often used in cognitive psychology, was used to assess eye movements during grocery shopping and explore possible associations with individual differences in personality traits (Study 5). For cognitive psychology, the findings of Studies 2-4 may provide guidance to develop cognitive trainings and interventions. For personality psychology, the confirmed feasibility of Study 5 (feasibility study) may expand its traditional methods repertoire by using eye tracking in real life. In the following part, it is first argued why the use of cognitive methods in personality research is important. Cognitive methods are here defined as research approaches that incorporate the understanding of cognitive processing and individual differences in cognitive performance of individuals. Second, the integration of cognitive and personality research is discussed more broadly.

The primary aim of using cognitive methods in personality research is to examine the processes that transpire in real-time transactions with the environment. In contrast, self- and

²⁰Parts of this section are in press as a book chapter in the Wiley-Blackwell encyclopedia of personality and individual differences: Vol. II. Research methods and assessment techniques (Copyright notice: John Wiley & Sons). This section does not exactly replicate the final version that is in press in the John Wiley & Sons book chapter. Original book chapter in press by John Wiley & Sons: Aschwanden, D., Allemand, M., & Hill, P. L. (in press). Cognitive methods in personality research. In B. J. Carducci (Editor-in-Chief & Vol Ed.), *The Wiley-Blackwell encyclopedia of personality and individual differences: Vol. II. Research methods and assessment techniques*. Hoboken, NJ: John Wiley & Sons.

observer-reports seek to capture generalizations that individuals make about themselves and others. Cognitive and self-report methods may or may not correspond with each other. For example, research has shown that Implicit Association Tests (IATs) predicted spontaneous Big Five behavior, but explicit measures (i.e., questionnaires) did not. In contrast, explicit measures, but not IATs, were related to self-rating of behavior (Steffens & Schulze-König, 2006). Furthermore, traditional personality research methods such as self-reports fail to capture many of the cognitive processes that transpire when individuals are exposed to stimuli, because individuals do not have conscious access to how they process stimuli in real time. Thus, individuals are not able to report on these processes (Robinson, 2004). Moreover, self-reports rely on subjectivity and retrospection. However, cognitive processes can be measured both in an objective (e.g., cognitive tests) and subjective way (e.g., self-reports of cognitive processes). Although self-report measures of personality show predictive validity for important life outcomes (Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007), there are important reasons to use cognitive measures in personality research. Investigations along cognitive signature of personality traits will be inherently valuable not only for advancing the scientific understanding of given traits, but also for helping to explain the reasons why personality traits appear to hold such consistent effects on important life outcomes. In other words, personality research using cognitive methods can elucidate the mechanisms linking personality traits to well-being and success across life domains.

The use of cognitive methods has considerable value to understand individual differences in personality processes and traits. However, it is unlikely that any cognitive measure can entirely tap a personality trait, because cognitive processes are dynamic in nature (cf. Robinson, 2007). In contrast, personality traits are relatively stable across various situations and contexts. Therefore, it is important to distinguish between micro-levels (e.g., reaction time in milliseconds) and macro-levels (e.g., working memory performance) of cognitive psychology. Looking at the micro-level may provide valuable insights into

personality behaviors, whereas looking at the macro-level may provide valuable insights into personality traits. Likewise, it is important to consider reliability and validity when choosing one's cognitive method for a specific research question in personality psychology. The use of cognitive methods makes a unique contribution to personality research, for example when (a) it comes to potential cognitive mechanisms that are involved in trait-outcome relations; (b) important information cannot be examined by self-reports or behavioral observations; and (c) cognitive processes may act as a moderator of trait-outcome relations. With regard to personality research studying individual differences in cognitive processes, it may be useful to widen the scope of investigation by taking third variables such as cognitive engagement or interests into account. It might be that such variables act as mediators or moderators of the relationship between cognition and personality. For example, individuals who enjoy cognitively demanding activities that involve abstract thinking, problem solving as well as reading, may be more open and show higher scores in problem solving tasks. Thus, it may be possible that cognitive engagement mediates the relationship between openness and problem solving abilities. Using cognitive methods in personality research certainly promotes a greater integration of cognitive and personality psychology where both areas can benefit from. For personality psychology, the traditional methods repertoire of self-reports and behavioral observations is expanded by cognitive methods. For cognitive psychology, a better understanding of personality differences in cognitive performance can help to develop cognitive trainings and interventions based on these personality differences.

5.4 Future Directions

Based on the findings of the current thesis, several implications for future research arise. As the implications of the empirical studies were discussed for each study separately in the preceding chapters, the implications given here are more broadly and integrative.

5.4.1 Merging Long-Term Development and Short-Term Dynamic Processes

The current thesis is based on longitudinal, intensive longitudinal (ambulatory assessment), and very intensive longitudinal (eye tracker) data. Hence, different methodological approaches were required, including longitudinal structural equation modeling and multilevel modeling. In doing so, the associations of interest were examined from the perspective of long-term development as well as short-term dynamic processes in daily life. However, these two temporal perspectives were considered separately (Figure 1, Part B), not integratively (Figure 4). This means, long-term development and short-term dynamic processes could not be explicitly linked in the present thesis. However, it seems important to model long-term developmental changes of personality-cognition relations combined with their short-term dynamic processes on a daily or momentary basis in order to answer research questions such as “do cognitive and open behaviors in daily life predict the development of cognition and openness across several years?”. Subsequently, new theories which contribute to the understanding of long-term development and short-term dynamic processes could be derived.

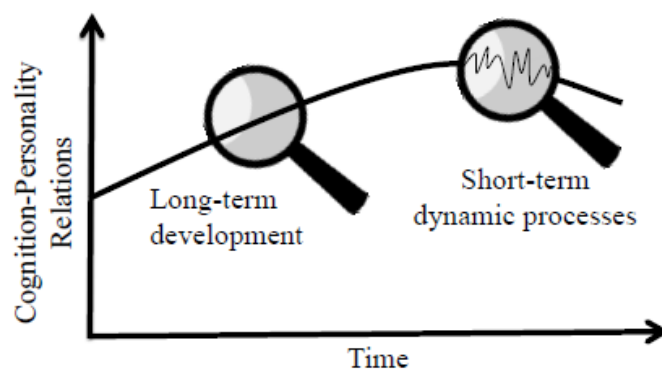


Figure 4. *Merging Two Time Scales*

Notes. Schematic representation of considering both temporal perspectives integratively (adapted from Nesselroade, 1991).

In order to merge features of both long-term designs (cf. Studies 1-3) and short-term dynamic processes methods (cf. Study 4), the *measurement burst design* (Nesselroade, 1991) or the *integrated trait-state model* (Hamaker, Nesselroade, & Molenaar, 2007) could be used in future investigations.

The *measurement burst design* is a design in which measurement bursts with short intervals (e.g., days as in Study 4) between observations are embedded into a longitudinal design where the measurement bursts are themselves separated by longer (e.g., years as in Studies 1-3) intervals (cf. Nesselroade, 1991; Ram & Gerstorf, 2009; Sliwinski, 2008; Stawski, MacDonald, & Sliwinski, 2015). For instance, the TESSERA framework is such a theory that explicitly links short- and long-term processes of personality development by addressing different manifestations of personality and by being applicable to different personality characteristics (Wrzus & Roberts, 2017). The TESSERA framework states that long-term personality development occurs because of repeated short-term processes. In turn, these short-term processes can be generalized as recursive sequence of triggering situations, expectancy, states/state expressions, and reactions (TESSERA). For cognition, no such theoretical framework has been found in current literature. However, measurement burst designs have been applied to separate short-term retest effects from long-term age-related cognitive change (Sliwinski, Hoffman, & Hofer, 2010) or to examine how long-term changes in cognitive ability are related to short-term changes in cognitive performance, cardiovascular function, and emotional experience (Ram, Gerstorf, Lindenberger, & Smith, 2011). Future cognitive research may develop a theory similar to the TESSERA framework for cognition. Moreover, the research field of cognition-personality relations would also benefit from a theoretical framework that explicitly links short- and long-term processes, although it should be borne in mind that no universal theory exists at this time (cf. section 1.1).

In addition, there is abundant room for further research in terms of short-term dynamic processes of cognition-personality relations. Study 4 indeed examined within-person

associations, but there is a need to better understand intraindividual variability of cognition-personality relations. Intraindividual variability is defined as “relatively short-term changes that are construed as more or less reversible” (Nesselroade, 1991; p. 215). Future work should examine the fluctuations, oscillations, and adaptations in cognitive and personality-related behaviors that manifest across closely spaced intervals such as seconds, minutes, hours, or weeks (cf. Ram & Gerstorf, 2009). In order to do so, sophisticated data analytic techniques such as linear and nonlinear dynamical systems are required (Boker, 2013; Boker & Bisconti, 2006).

The *integrated trait-state model* (Hamaker et al., 2007) can be used to investigate whether individuals are characterized by identical state structures (intraindividual variability), and whether this state structure is identical to the trait structure (intraindividual stability). This model offers a method by which traits and states can be linked, both analytically and theoretically. It could answer research questions such as “is there a universal cognition-personality state structure that applies to all and if so, does this cognition-personality state structure coincide with the cognition-personality trait structure?”. To be more specific, one could investigate whether there is a universal intraindividual variability of cognitive engagement behaviors and open behaviors and if so, whether this corresponds with the intraindividual stability of cognitive engagement and openness. If this proves to be the case, it would imply that variability within an individual takes place on the exact same cognition-personality dimensions that describe the enduring cognition-personality differences between individuals (cf. Hamaker et al., 2007). Understanding the trait–state issue of cognition-personality relations may help for studying the dynamics of trait change.

5.4.2 Interventions: Combining Elements from Cognitive and Personality Psychology

The findings of the present thesis (i.e., Studies 2-4) may have important implications for the development of future intervention strategies. For example, the results of Study 2 revealed a positive association between reasoning and openness. This could provide guidance

for researchers to develop a cognitive intervention (i.e., reasoning training) that may also positively impact the personality trait openness. In fact, a previous study already found that a reasoning training of 16 weeks resulted in higher levels of participants' openness (Jackson et al., 2012). However, it should be noted that the increase of openness may also be the outcome of an unintended effect of the intervention (e.g., participants view themselves as more open because of their training participation) rather than a change in reasoning per se. Furthermore, another study failed to replicate Jackson et al.'s findings (Sander et al., 2017). Certainly, further work is required to determine the impact (and mechanism) of a reasoning training on openness, but this line of research uncovers the potential of cognitive interventions affecting personality traits. Inversely, previous work suggests that it seems promising to develop specific cognitive interventions for different personality types (Studer-Luethi et al., 2012). To illustrate, the findings of Studer-Luethi et al. indicate that participants low on neuroticism benefit more from a dual n-back working memory training, whereas highly neurotic participants profit more from a single n-back working memory training. The authors conclude that individual differences in personality traits should be considered for cognitive interventions in order to optimize the training efficacy. Furthermore, clinical interventions that match to the individual's personality may improve their acceptability, adherence, and effectiveness. This is exemplified in a clinical intervention designed to reduce behavioral symptoms of dementia, where demented individuals significantly improved engagement, alertness, and attention if specific leisure activities were matched with their personality compared to demented individuals whose activities were mismatched with their personality (Kolanowski, Litaker, Buettner, Moeller, & Costa, 2011). This means, personality-tailored interventions may be particularly effective in achieving the desired outcome even when the aim of the intervention is not to change personality (cf. Luchetti et al., 2016).

Furthermore, one could also think about combined cognitive-personality interventions. Based on the findings of Study 3, an intervention where individuals solve cognitive tasks and

engage in exercises that are tailored to enhance emotional stability behaviors is suggested. As such, elements from both cognitive psychology (cognitive tasks) and personality psychology (exercises) are combined and integrated in one intervention. When combining cognitive and personality interventions, it may be helpful to consider the historical development of interventions in the two domains. Whereas interventions are well established in cognitive psychology, they are currently emerging in personality psychology. In cognitive psychology, interventions are popular since the past few decades (Acevedo & Loewenstein, 2007), and the research area of cognitive intervention studies is growing rapidly so that several reviews have been conducted (e.g., Martin, Clare, Altgassen, Cameron, & Zehnder, 2011; Papp, Walsh, & Snyder, 2009; Reijnders, van Heugten, & van Boxtel, 2013). For healthy older individuals, these interventions typically focus on cognitive training or cognitive stimulation to prevent or minimize the effects of cognitive aging. Whereas cognitive training generally involves guided practice of specific tasks to increase or maintain particular cognitive abilities (e.g., working memory; Guye & von Bastian, 2017; von Bastian, Langer, Jäncke, & Oberauer, 2013), cognitive stimulation promotes the involvement in activities that are aimed at an enhancement of general cognitive functioning (cf. Tardif, & Simard, 2011). In personality psychology, there is a distinct lack of research investigating techniques to change personality traits (Roberts et al., 2017), and only recent developments have led to an interest in personality interventions (e.g., Stieger et al., manuscript in preparation). The reason why personality interventions are still in its infancy may be due to prior generations of researchers that painted a picture in which personality traits were either perfectly stable or permanently variable (Roberts, 2009). Though, clinicians have been changing personality traits for many years (Chapman, Hampson, & Clarkin, 2014). For example, clinical researchers have identified the personality trait neuroticism as key contributor to psychopathology (Lahey, 2009), and suggested that it should be the primary focus of interventions given its widespread relation to various forms of psychopathology (Barlow, Sauer-Zavala, Carl, Bullis, & Ellard, 2014).

Recently, also modern personality trait theories state that personality traits appear to be amenable to intervention (Roberts et al., 2017). This fact opens the door to a new era of research that more strongly links personality and clinical psychology (e.g., Allemand, & Flückiger, 2017), but also cognitive psychology and other groups who are interested in changing people and their behaviors in order to help them with their lives or to promote healthy aging.

The afore-mentioned developmental difference of interventions may be of use for personality psychology in particular. Identifying aspects of cognitive interventions that are applicable to personality interventions may prevent personality psychology from reinventing the wheel and allow to benefit from existing knowledge (Mroczek, 2014). Put differently, personality psychology might learn from cognitive psychology, studying the efforts that have been made in this research area and potentially starting with a strong base in initial attempts at personality interventions (cf. Mroczek, 2014). However, the distinction between maximal performance and typical behaviors should be incorporated when designing combined cognitive-personality interventions. First, the target of the intervention (maximal performance and/or typical behaviors) must be defined. Subsequently, corresponding elements from cognitive and personality psychology can be chosen. As a result, it is supposed that the intervention is designed as efficient as possible and elements from cognitive and personality psychology may ideally complement each other.

Moreover, interventions can be focused on different levels of the targeted construct. For example, Allemand, and Flückiger (2017) distinguish between three levels at which personality intervention strategies aim, that is at broad (traits), medium (habits), and narrow (states) levels. They argue that it seems easier to start modifying on the narrow levels (states) than on the broad levels (traits) because states are more variable and probably more responsive to intended change efforts than broader constructs such as traits (Chapman et al., 2014). The underlying idea is that the accumulation of changes at the narrow level (states)

would eventually lead to change at the broad level (traits) through bottom-up processes of change and habituation (Wrzus & Roberts, 2017). Put differently, new behaviors and experiences may become learned, habitual and automatized through repeated practice and reinforcement over time (Allemand & Flückiger, 2017). Similarly, cognitive intervention strategies can be focused on levels of maximal performance and everyday behaviors. In the suggested example of Study 3, cognitive tasks target at maximal performance (general cognition), but it is also possible to include exercises that aim to enhance or reduce cognitive behaviors such as cognitive engagement or cognitive complaints. If the target of the intervention is to improve maximal performance, structured practice on tasks (power and speed tasks) relevant to aspects of cognitive functioning may be considered. If the aim is to change cognitive behaviors or everyday functioning, exercises close to everyday life may be chosen (e.g., reading a book to stimulate cognitive engagement).

Taking this intervention approach one step further, individualized intervention programs could be designed because many different cognition-personality associations may contribute to healthy aging. For example, good working memory performance and low levels of neuroticism as well as good reasoning performance and high levels of openness may maintain the functional ability that enables well-being in older adults. Furthermore, individuals may have different reasons to participate in an intervention and may not as much benefit from a standard intervention as they could from an individually designed intervention. Individually designed interventions would target specific cognition-personality combinations (e.g., working memory and neuroticism for person A, reasoning and openness for person B) to maintain or enhance individually important outcomes (e.g., better working memory performance for person A, becoming more open for person B). To assign older adults to their individualized intervention, different indicators could be consulted, for instance cognitive performance, cognitive complaints, cognitive engagement, personality traits, personality behaviors, or personal goals, but also their mobile phone usage. The latter can be exemplified

by Chittaranjan et al. (2011) who developed an automatic method using supervised learning to infer the personality type based on mobile phone usage. Together, these indicators yield an individual profile. Subsequently, an algorithm with clearly defined criteria for the individually important outcomes could assist to identify the appropriate profile-based intervention for a specific individual (see Figure 5).

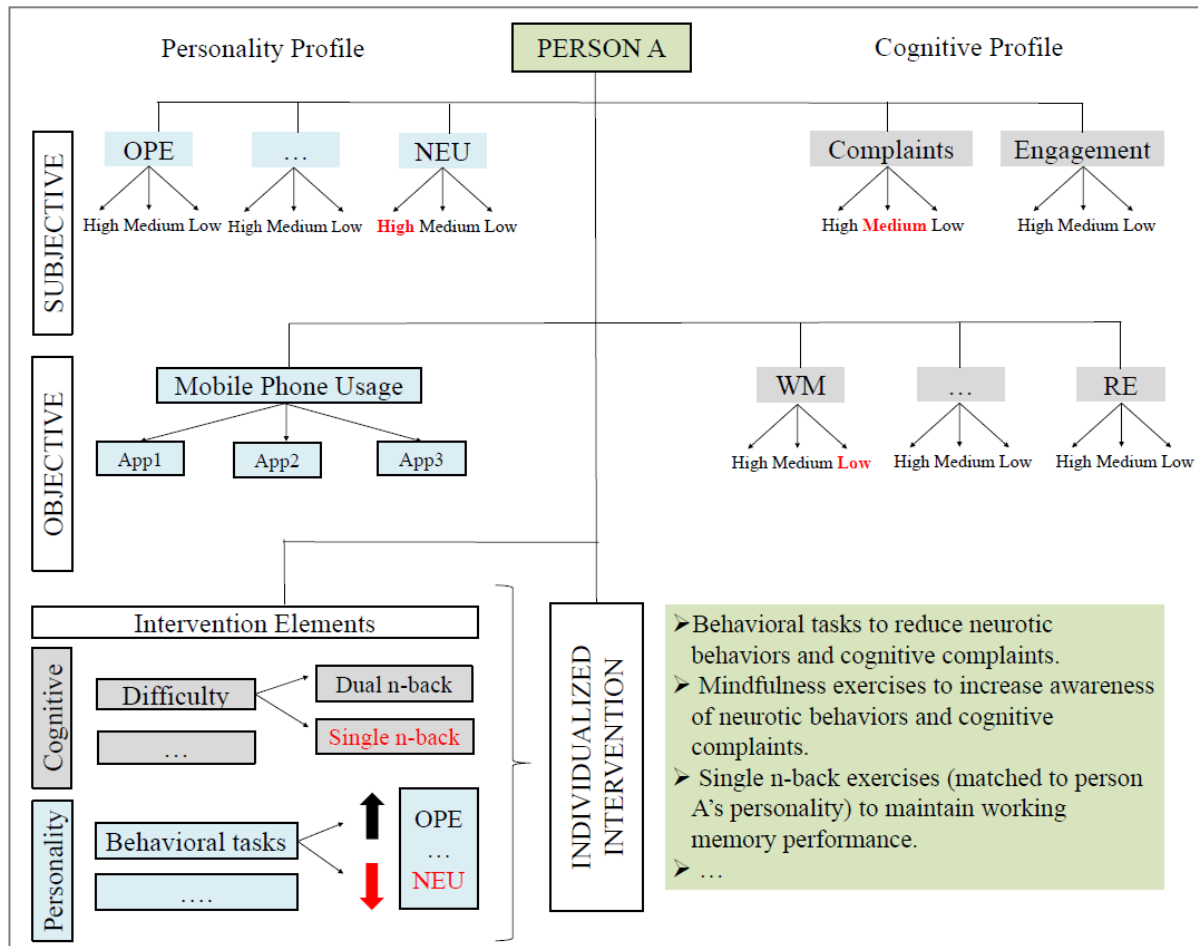


Figure 5. A Simplified Illustration of a Possible Algorithm

Notes. OPE = openness; NEU = neuroticism; App = Applications; WM = working memory; RE = reasoning. In this example, Person A complains about difficulties to focus, and to remember events, engagements, names, and phone numbers. Person A is afraid that these problems will increase in the near future. Thus, Person A aims to maintain or even increase her or his working memory performance (individually important outcome). The personality profile resulted amongst other things that Person A is highly neurotic. The cognitive profile yielded amongst other things that Person A sometimes complains about her or his cognition in general. Furthermore, Person A shows a rather weak working memory performance compared to her or his normative sample. Based on Person A's individual profile (personality + cognitive profile), elements from both cognitive and personality psychology should be considered to provide the appropriate individualized intervention for Person A.

Future work is now required to test the applicability of cognitive interventions for different personality types, personality interventions depending on cognitive characteristics, and combined cognitive-personality interventions. If ultimately successful, these interventions will probably be cheaper to develop than others such as medical treatments (Mroczek, 2014). As such, the implications of the present thesis may offer a new research niche in the area of intervention studies.

5.4.3 Healthy Aging: A Holistic Perspective Based on the Lifespan

The WHO (2015) considers healthy aging as a lifespan and holistic process as it starts at birth (lifespan) and it includes personal and health characteristics as well as the environment (holistic). However, the present thesis focused on cognition-personality relations in older age only, and thus this lifespan and holistic perspective lacks. Future research should therefore concentrate on the following recommendations that will help to satisfy the definition of healthy aging in a more holistic sense that is based on the lifespan.

First, it makes sense to investigate cognition-personality relations that contribute to healthy aging not only in older age, but across the whole lifespan because healthy aging is conceptualized as starting at birth with genetic inheritance (WHO, 2015). It would be interesting to examine how cognition-personality relations develop from early childhood to the fourth age (Baltes, & Smith, 2003). It seems possible to hypothesize that this relation is u-shaped across the lifespan, peaking in infancy and older age when cognitive abilities are more vulnerable and undergo larger developmental changes. That is, cognitive abilities tend to increase throughout early adulthood and then begin to show declines in late adulthood (cf. Craik & Bialystok, 2006). It may be that the bidirectional influence of cognition–personality associations appears stronger in children and young adults when both domains are developing. In middle adulthood, cognition and personality will continue to influence each other, but maybe to a smaller degree because both domains seem to be relatively stable during this time period. Later in life, it may be that the associations again appear stronger when older adults

realize that their cognitive abilities decline and want to “fight against it” or if they desire to improve their cognitive performance. By way of a brief illustration, a fictive longitudinal study should be imagined (similarly to the Seattle Longitudinal Study, see Schaie et al., 2004). This fictive study starts when participants are at the age of seven years (school entry), and continues them to follow across 80 years with measurement occasions every two years. At the end of this fictive study, it is possible to compare the intraindividual development of cognition-personality relations across specific time periods. For example, the cross-lagged effect of openness on reasoning from childhood (i.e., openness at the age of 7 years and reasoning at the age of 13 years) can be compared with the one from middle adulthood (i.e., openness at the age of 37 years and reasoning at the age of 43 years) of the same person. Referring to the hypothesized u-shape, it would be expected that the effect size of the cross-lagged effect from childhood is larger than the cross-lagged effect from middle adulthood due to the assumed stronger bidirectional influence earlier in life.

Second, healthy aging is conceptualized as a dynamic process as it includes various interactions (e.g., with the environment) and changes such as physiological changes of health characteristics (WHO, 2015). In contrast, the present thesis focused mainly on static snapshots rather than dynamics of cognition-personality relations. Put differently, Studies 2-4 investigated the *levels* of cognition and personality (static snapshots), but not *changes* in these domains (dynamics). Therefore, one potential line of future research is to study the cognition-personality relations themselves more dynamically (i.e., changes in cognition and personality). It is possible that changes in personality may be more predictive for cognitive performance than levels of personality at one point in time and vice versa. For example, previous research showed that changes in personality traits predict life outcomes such as mortality (Mroczek & Spiro, 2007), substance use (Hampson, Tildesley, Andrews, Luyckx, & Mroczek, 2010), and health (Turiano et al., 2012). Similarly, changes in cognition also predict life outcomes such as mortality (Anstey, Luszcz, Giles & Andrews, 2001), Alzheimer’s

disease (Zahodne, Manly, MacKay-Brandt, & Stern, 2013), and declines in activities of daily living (Amieva et al., 2008). It is thus reasonable to assume that changes in either domain may be predictive for the other domain, and beyond that, it would be interesting to examine whether or not changes are more predictive than levels.

Third, healthy aging includes various personal and health characteristics (WHO, 2015). This thesis is limited by considering only traits and behaviors related to the Big Five personality model. However, another possible area of future research would be to investigate a more comprehensive personality framework that considers the whole person (McAdams & Pals, 2006) and a variety of health characteristics such as physiological risk factors (e.g., high blood pressure) or health-related behaviors (e.g., physical activity, nutrition). These health characteristics may mediate or moderate different cognition-personality relations. Therefore, another interesting line of investigation could be to study possible mediators and moderators that underlie these relations (cf. Study 3). This would be an important step forward in developing a better understanding of these relations and to paint a more holistic picture of the factors that contribute to healthy aging. It is possible that more than only one factor underlies different cognition-personality relations. Such factors should be identified and included in multiple mediation models to determine which are most pertinent. Additionally, it seems reasonable to expect different mediators and/or moderators for different cognition-personality relations. For instance, nutrition may be a possible mediator between general cognition and conscientiousness, but not between processing speed and extraversion.

5.5 Concluding Remarks

Three general conclusions are drawn based on the findings of this thesis. First, cognition-personality relations are evident over years and over days. It is now implied to integrate features of long-term designs (Studies 1-3) and short-term dynamic processes' methods (Studies 4-5). Hence, the same sample could be investigated on both time scales to answer research questions about the long-term developmental changes of personality-

cognition relations combined with their short-term dynamic processes in daily life. Second, it is important to examine cognition as a predictor of personality traits, because cognition may shape personality traits over time (Studies 2-3). Future longitudinal studies should not persist on investigating personality as a predictor of cognition only, but rather focus on the bidirectionality of cognition-personality relations if allowed by the study design. Third, cognitive engagement plays an important role with regard to cognitive performance (e.g., perceptual speed in Study 1) and personality behaviors in daily life (e.g., openness in Study 4). Therefore, older adults should be encouraged to engage in cognitive activities as it seems a protective factor for cognitive performance and daily open behaviors.

The current thesis makes a significant contribution to the aging research by offering new insights into cognition-personality relationships from both long-term and short-term perspectives. Furthermore, the findings of this thesis extend the basis of cognition-personality research and could help to develop a theoretical cognition-personality model. Future research might build upon the findings presented here by unravelling these relationships across the whole lifespan and testing the proposed interventions combining elements from both cognitive and personality psychology to promote healthy aging.

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Appendix

Practical Recommendations from Study 5 (Feasibility Study)

Feasibility

1. Using the wireless Dikablis Professional Eye Tracking Glasses, it was no problem to record eye movements if participants wore glasses (reading glasses or varifocals).
2. As participants move freely during grocery shopping, the connection cable from the eye tracker glasses to the tablet should be tapped down so that it cannot be displayed and thus interrupt the recording.
3. The WLAN connection might disrupt if the distance from the participant to the router is too large (what easily can happen if the supermarket is big). In this case, the eye tracker data are stored on the tablet (offline) and can be downloaded later. However, it is not possible to monitor the cameras on the laptop in real-time if there no WLAN connection.

Video Coding

4. The video coding is very time-intensive if no markers are used. Depending on the area of interest that is coded, it may last up to 24 hours and more to code a video of 10 minutes. Videos should be double-coded to provide an inter-rater-reliability.
5. The illumination in the supermarket may change in different sections. Furthermore, some packing colors (e.g., red) may interact with the illumination. Both of these factors may influence the quality of the video material. In turn, this may cause difficulties to recognize specific products during the video coding process and lead to a weaker inter-rater-reliability.

Participants

6. Participants should pay in cash rather than by credit card (if it is a chip card) as the scene camera will record where they look at, that is the numeric keypad (PIN code).

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